Fecal Coliform TMDL (Total Maximum Daily Load) Development for Upper Blackwater River, Virginia

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for
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EXECUTIVE SUMMARY

Fecal Coliform Impairment

The Upper Blackwater River was placed on the Commonwealth of Virginia's 1998 303(d) List of Impaired Waters because of violations of the fecal coliform bacteria water quality standard, as well as the general (benthic) water quality standard. This TMDL focuses on the fecal coliform impairment. Based on exceedances of this standard recorded at Virginia Department of Environmental Quality (VADEQ) monitoring stations, the stream does not support primary contact recreation (e.g. swimming, wading, and fishing). The applicable state standard specifies that the number of fecal coliform bacteria shall not exceed a maximum allowable level of 1,000 colony forming units (cfu) per 100 milliliters (ml) (Virginia State Law 9VAC25-260-170). Alternatively, if data is available, the geometric mean of 2 or more observations taken in a thirty-day period should not exceed 200 cfu/100 ml. A review of available monitoring data for the study area indicated that fecal coliform bacteria were consistently elevated above the 1,000 cfu/100 ml standard. In TMDL development, the geometric mean standard of 200 cfu/100 ml was used, since continuous simulated data was available.

Sources of Fecal Coliform

Potential sources of fecal coliform include both point source and nonpoint source contributions. Nonpoint sources include wildlife; grazing livestock; land application of manure; land application of biosolids; urban/suburban runoff; failed, malfunctioning, and operational septic systems, and uncontrolled discharges (straight pipes, dairy parlor waste, etc.). To account for unquantifiable loads from known wildlife species, a background load was applied to all land segments equal to 10% of the total wildlife load quantified. There are no permitted point discharges is in the Upper Blackwater drainage area.

Water Quality Modeling

The US Geological Survey (USGS) Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate existing conditions and perform TMDL allocations. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities were explicitly accounted for in the model.

Thirty-minute flows from the US Geological Survey gage (#02056900) on the Blackwater River, at Smith Mountain Lake, VA, were used to calibrate hydrologic flows for the Blackwater River watershed in the HSPF model, thereby improving confidence in computed discharges generated by the model. The representative hydrologic period used for calibration ran from October 1, 1994 through September 30, 1998. The model was validated using daily flows recorded at the same gauging station from October 1, 1980 through September 30, 1981 and from January 1, 1991 through September 30, 1994. The time periods covered by calibration and validation represent a broad range of hydrologic and climatic conditions and is representative of the 20-year precipitation and discharge record. For purposes of modeling watershed inputs to in-stream water quality, the Upper Blackwater drainage area was divided into four subwatersheds. The model was calibrated for water quality predictions using data collected at VADEQ monitoring stations between January 1993 and December 1995, and validated using data collected between January 1991 and December 1992. All allocation runs were conducted using precipitation data from January 1991 to December 1995.

Existing Loadings and Water Quality Conditions

Wildlife populations and ranges; biosolids application rates and practices; rate of failure, location, and number of septic systems; pet populations, number of cattle and other livestock; and information on livestock and manure management practices for the Upper Blackwater watershed were used to calculate fecal coliform loadings from land-based nonpoint sources in the watershed. The estimated fecal coliform production and accumulation rates due to these sources were calculated for the watershed and incorporated into the model. To accommodate the structure of the model, calculation of the fecal coliform accumulation and source contributions on a monthly basis accounted for seasonal variation in watershed activities such as wildlife feeding patterns and land application of manure. Also represented in the model were direct nonpoint sources of properly-functioning septic systems, uncontrolled discharges, direct deposition by wildlife, and direct deposition by livestock located within 50 feet of a stream.

Contributions from all of these sources were represented in the model to establish existing conditions for the watershed over the representative hydrologic period (1991-1995). Under existing conditions (1999), the HSPF model provided a comparable match to the VADEQ monitoring data, with output from the model indicating violations of both the instantaneous and geometric mean standards throughout the watershed.

Load Allocation Scenarios

The next step in the TMDL process was to determine how to proceed from existing watershed conditions to reduce the various source loads to levels that would result in attainment of the water quality standards. Because Virginia's fecal coliform standard does not permit any exceedance of the standard, modeling was conducted for a target value of 0% exceedance of the 200 cfu/100 ml geometric mean standard. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality. Modeling of these scenarios provided predictions of whether the reductions would achieve the target of 0% exceedance. Periods of low flow were critical in terms of water quality. The set of scenarios explored pointed to the importance of reducing direct deposition loadings to the stream. The final load allocation scenario required a 100% reduction in uncontrolled discharges, a 100% reduction in direct deposition to the stream by livestock, and a 75% reduction in direct deposition to the stream sections by wildlife.

Margin of Safety

In order to account for uncertainty in modeled, output a margin of safety (MOS) was incorporated into the TMDL development process. A margin of safety can be incorporated implicitly in the model through the use of conservative estimates of model parameters, or explicitly as an additional load reduction requirement. Individual errors in model inputs, such as data used for developing model parameters or data used for calibration, may affect the load allocations in a positive or a negative way. The purpose of the MOS is to avoid an overall bias toward load allocations that are too large for meeting the water quality target. An explicit MOS equal to 5% of the targeted geometric mean concentration of 200 cfu/100 ml was used in the development of this TMDL. As a result, allocations were made based on a modeled 30-day geometric mean not exceeding 190 cfu/100 ml.

Recommendations for TMDL Implementation

The goal of this TMDL was to develop an allocation plan that can be met during the implementation phase. Virginia's 1997 Water Quality Monitoring, Information and Restoration Act states in section 62.1-44.19.7 that the "Board shall develop and implement a plan to achieve fully supporting status for impaired waters". To this end, funds have been approved to immediately follow this TMDL development to establish a monitoring scheme and to develop the strategies for a phased implementation plan for restoring the water quality of the Upper Blackwater impairment to levels identified in this TMDL.

The TMDL developed for the Upper Blackwater impairment provides allocation scenarios that will be a starting point for developing implementation strategies. Modeling shows that periods of low flow are the most critical for water quality. This result points out the need to reduce direct deposition of fecal coliform bacteria into the stream. Additional monitoring aimed at targeting these reductions is critical to implementation development. Bacteria source tracking to identify sources of contamination and an improved inventory of wildlife in the impairment area will contribute greatly to the implementation effort. Once established, continued monitoring will aid in tracking success toward meeting water quality milestones.

A phased implementation plan is essential to the process of restoring water quality. The goal of the first phase is to foster local support for the implementation plan. The model scenario developed for the first phase included a 50% reduction in failed septic systems, a conversion of 50% of poor pasture to good pasture, a 100% reduction in uncontrolled discharges, and a 90% reduction in direct deposition to the stream by livestock. The land-based load reductions prescribed for the first phase of the implementation plan are not incorporated into the final allocation, since their use does not ensure zero violations of the water quality standard. The first phase of the implementation represents preliminary steps in achieving the final allocation. A phased implementation plan is necessarily an iterative process. There is a measure of uncertainty associated with the final allocation development process. Continued monitoring can provide insight into the effectiveness of implementation strategies, the need for amending the plan, and/or progress toward the eventual removal of the impairment from the 303(d) list.

Also critical to the implementation process is public participation. Permitted point sources provide a limited contribution to the overall water quality problem. Nonpoint direct deposition to streams appears to be the critical factor in addressing the problem. These sources cannot be addressed without public understanding of and support for the implementation process. Stakeholder input will be critical from the onset of the implementation process in order to develop an implementation plan that is truly implementable.

Public Participation

During development of the TMDL for the Upper Blackwater, public involvement was encouraged through five meetings. The first, semi-public meeting, included members of each stakeholders group and outlined the development process and subsequent meetings. Three additional meetings were held for the public at large, and focused on the upper four impairments in the Blackwater River watershed. A basic description of the TMDL process and the agencies involved was presented at the first of the three public meetings. During the second public meeting, details of the hydrologic calibration and pollutant sources were presented. The final model simulations and the TMDL load allocations were presented during the final public meeting. Public understanding of and involvement in the TMDL process was encouraged. Input from these meetings was utilized in the development of the TMDL and improved confidence in the allocation scenarios developed.

In addition to the open public meetings, MapTech, Inc. conducted a meeting on November 22, 1999 with twelve local farmers, identified and assembled by the Franklin County Farm Bureau. Through this meeting, insight into local farming practices that impact the delivery of fecal coliform to the streams was gained through conversation and a written survey of agricultural practices. The survey results formed much of the basis of the modeling efforts.

In addition to the more direct public presentations described above, two special one-hour programs, the second public meeting held on February 16, 2000, the third public meeting held on March 15, 2000 were video-taped and televised. These programs were available to 8,500 county households with cable television access, as well as local institutions such as Ferrum College.

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1. INTRODUCTION

1.1 Background

EPA's document, *Guidance for Water Quality-Based Decisions: The TMDL Process* (USEPA, 1999) states:

> *According to section 303(d) of the Clean Water Act and EPA water quality planning and management regulations, States are required to identify waters that do not meet or are not expected to meet water quality standards even after technology-based or other required controls are in place. The waterbodies are considered water quality-limited and require TMDLs .*
>
> *. . . A TMDL, or total maximum daily load, is a tool for implementing State water quality standards and is based on the relationship between pollution sources and in-stream water quality conditions. The TMDL establishes the allowable loadings or other quantifiable parameters for a waterbody and thereby provides the basis for States to establish water quality-based controls. These controls should provide the pollution reduction necessary for a waterbody to meet water quality standards.*

According to the *1998 303(d) Total Maximum Daily Load Priority List and Report* (VADEQ, 1998), the Upper Blackwater is prioritized as "high" on the list for TMDL development and carries an agency watershed ID of VAW-L08R. VADEQ has identified the Upper Blackwater River as being impaired with regard to the fecal coliform bacteria water quality standard, as well as the general (benthic) water quality standard. This TMDL focuses on the fecal coliform impairment. The impaired stream segment has a length of 9.83 miles, beginning near Callaway, VA where the North and South Forks join to form the Blackwater River and ending near the Rt. 732 dead end road, at the Hay Run mouth on the Blackwater River.

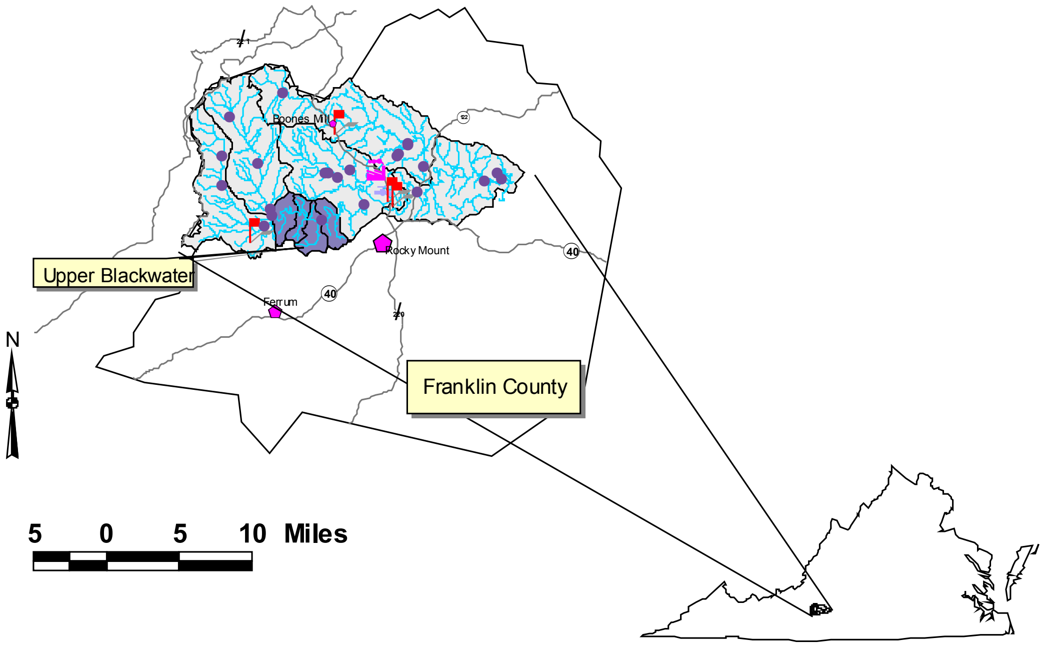

Figure 1.1 Location of the Upper Blackwater watershed.

The Upper Blackwater River is part of the Blackwater River watershed, located in Franklin County, Virginia, just north of Rocky Mount and approximately 15 miles to the south of Roanoke, Virginia (Figure 1.1). The Blackwater River watershed empties into Smith Mountain Lake, a reservoir on the Roanoke River. The Roanoke River flows southeast through a series of two additional reservoirs (John H. Kerr Reservoir and Gaston Lake), eventually emptying into the Albermarle Sound. The Blackwater River watershed is located within the Upper Roanoke hydrologic unit (USGS No. 03010101), and the Virginia hydrologic planning unit L08. The total area of the Blackwater River watershed is approximately 108,000 acres, with forest and agriculture as the primary land uses (Figure 1.2). Of this, the Upper Blackwater watershed is approximately 8,815 acres comprised of forest (55.8%), agricultural (40.1%), and urban (4.1%) land uses. The estimated population within the Upper Blackwater drainage area in 1999 was 716. Franklin County ranks 2nd, among Virginia counties, for the number of Dairy cows, 6th for the number of all cattle and calves, 19th for beef cattle, and 3rd for corn silage. (VASS, 1999). The Blackwater River Watershed received average annual precipitation of approximately 47 inches, and produced an average annual runoff volume of approximately 17 inches between 1977 and 1998.

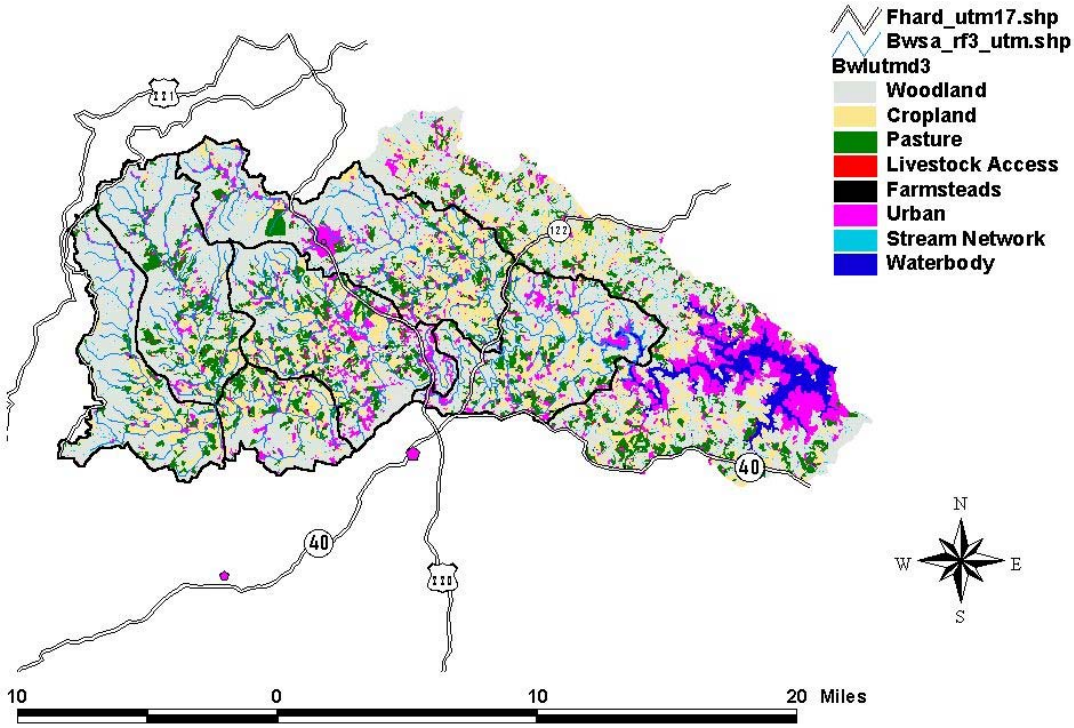

Figure 1.2 Land uses in the Blackwater River watershed.

1.2 Applicable Water Quality Standards

Virginia state law 9VAC25-260-10 (Designation of uses.) indicates:

A. All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish.

♦

D. At a minimum, uses are deemed attainable if they can be achieved by the imposition of effluent limits required under §§301(b) and 306 of the Clean Water Act and cost-effective and reasonable best management practices for nonpoint source control.

♦

G. The [State Water Quality Control] board may remove a designated use which is not an existing use, or establish subcategories of a use, if the board can demonstrate that attaining the designated use is not feasible because:

1. Naturally occurring pollutant concentrations prevent the attainment of the use;

2. *Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation requirements to enable uses to be met;*

♦

6. *Controls more stringent than those required by §§301(b) and 306 of the Clean Water Act would result in substantial and widespread economic and social impact.*

Additionally, Virginia state law 9VAC25-260-170 (Fecal coliform bacteria; other waters.) indicates:

A. *General requirements. In all surface waters, except shellfish waters and certain waters addressed in subsection B of this section, the fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a 30-day period, or a fecal coliform bacteria level of 1,000 per 100 ml at any time.*

The Upper Blackwater River was listed on the Virginia Department of Environmental Quality (VADEQ) 1998 303(d) list as being impaired with regard to the fecal coliform bacteria water quality standard, as well as the general (benthic) water quality standard. This TMDL focuses on the fecal coliform impairment. Sufficient fecal coliform bacteria standard violations were recorded at VADEQ water quality monitoring stations to indicate that the recreational use designations are not being supported (VADEQ 1998).

Most of the VADEQ ambient water quality monitoring is done on a monthly or quarterly basis. This sampling frequency does not provide the two or more samples within 30 days needed for use of the geometric mean part of the standard. Therefore, VADEQ used the 1,000 cfu/100 ml standard in the 1996 and 1998 303(d) assessments of the fecal coliform bacteria monitoring data. A five-year time span was used for the assessment period.

2. TMDL ENDPOINT AND WATER QUALITY ASSESSMENT

2.1 Selection of a TMDL Endpoint and Critical Condition

The Upper Blackwater River was initially placed on the Virginia 1996 303(d) list of impaired waters based on monitoring performed between 1991 and 1995, and remained on the list for the 1998 assessment. Elevated levels of fecal coliform bacteria recorded at VADEQ ambient water quality monitoring stations showed that this stream segment does not support the primary contact recreation use.

The first step in developing a TMDL is the establishment of in-stream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. In-stream numeric endpoints, therefore, represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. For the Upper Blackwater TMDL, the applicable endpoints and associated target values can be determined directly from the Virginia water quality regulations (Section 1.2). In order to remove a waterbody from a state's list of impaired waters; the Clean Water Act requires compliance with that state's water quality standard. Since modeling provided simulated output of fecal coliform concentrations at 15-minute intervals, assessments of TMDLs were made using the geometric mean standard of 200 cfu/100 ml. Therefore, the in-stream fecal coliform target for this TMDL was a geometric mean not exceeding 200 cfu/100 ml.

Fecal coliform violations within the Upper Blackwater watershed are attributed to both nonpoint and direct in-stream sources. Critical conditions for waters impacted by nonpoint sources generally occur during periods of wet weather and high surface runoff. In contrast, critical conditions for point source-dominated systems generally occur during low flow and low dilution conditions.

A graphical analysis of fecal coliform concentrations and discharge showed that there was no obvious critical flow level (Figure 2.1). That is, the analysis showed no obvious dominance of either nonpoint sources or point sources. High concentrations were recorded in all flow regimes. Based on this analysis, a time period for calibration and validation of the model was chosen based on the overall distribution of wet and dry seasons (Section 4.5). The resulting time period for calibration was October 1994 thru September 1998. For validation, the time period selected was October 1980 thru September 1981 and January 1991 thru September 1994.

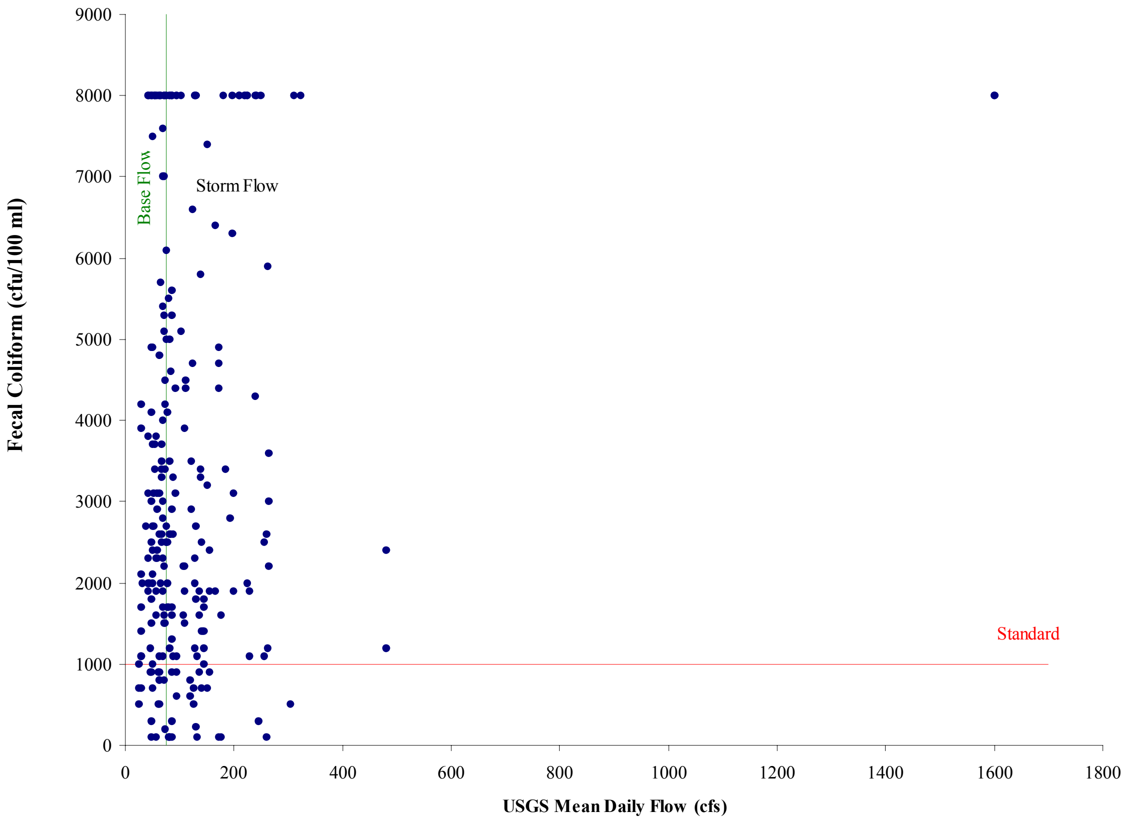

Figure 2.1 Relationship between fecal coliform concentrations and discharge in the Upper Blackwater watershed.

2.2 Discussion of In-stream Water Quality

This section provides an inventory and analysis of available observed in-stream fecal coliform monitoring data throughout the Blackwater River watershed. Since water quality data are limited, an examination of all data available for the entire Blackwater River watershed, including those collected on the Upper Blackwater River, were analyzed. Sources of data and pertinent results are discussed.

2.2.1 Inventory of Water Quality Monitoring Data

The primary sources of available water quality information are:

- two VADEQ in-stream monitoring stations located in the Upper Blackwater River;
- water quality monitoring conducted by MapTech, Inc. as part of the services contracted for this TMDL; and

- a study conducted by Ferrum College in cooperation with MapTech Inc., *Preliminary Fecal Coliform Assessment in the Blackwater River Watershed* (Yagow et al., 1999).

2.2.1.1 Water Quality Monitoring Conducted by VADEQ

Data from in-stream fecal coliform samples, collected by VADEQ, for the Upper Blackwater River are available from April 1989 to present. Samples were taken for the expressed purpose of determining compliance with the state standard limiting concentrations to less than 1,000 cfu/100 ml. Therefore, as a matter of economy, samples showing fecal coliform concentrations below 100 cfu/100 ml or in excess of 8,000 cfu/100 ml were not further analyzed to determine the precise concentration of fecal coliform bacteria. The result is that reported concentrations of 100 cfu/100 ml most likely represent concentrations below 100 cfu/100 ml, and reported concentrations of 8,000 cfu/100 ml most likely represent concentrations in excess of 8,000 cfu/100 ml. Table 2.1 summarizes the fecal coliform samples collected at the two VADEQ in-stream monitoring stations. Monitoring site locations are shown in Figure 2.2.

Table 2.1 Summary of water quality sampling conducted by VADEQ.

Impairment and Station Number	Count (#)	Minimum (cfu/100 ml)	Maximum (cfu/100 ml)	Mean (cfu/100 ml)	Median (cfu/100 ml)	Violations (%)
South Fork						
4AGCR000.01	127	100	7,600	544	200	13%
4ABSF001.15	127	100	8,000	2,889	2,200	86%
North Fork						
4ABNR009.36	120	100	8,000	808	300	23%
4ABNR004.56	120	100	6,700	761	500	20%
4ABNR000.40	116	100	8,000	5,130	5,700	89%
Upper Blackwater						
4ABWR061.20	**141**	**100**	**8,000**	**3,679**	**2,800**	**86%**
4ABWR054.81	**118**	**100**	**8,000**	**3,295**	**2,400**	**78%**
Middle Blackwater						
4ABWR045.80	151	100	8,000	2,392	1,300	58%
4ALLE005.22	121	100	8,000	4,277	3,500	94%
4ATEL001.02	122	100	8,000	3,000	2,200	79%
4AXKF000.20	24	4,800	8,000	7,775	8,000	100%
4AXKF000.40	23	100	8,000	4,370	3,800	91%

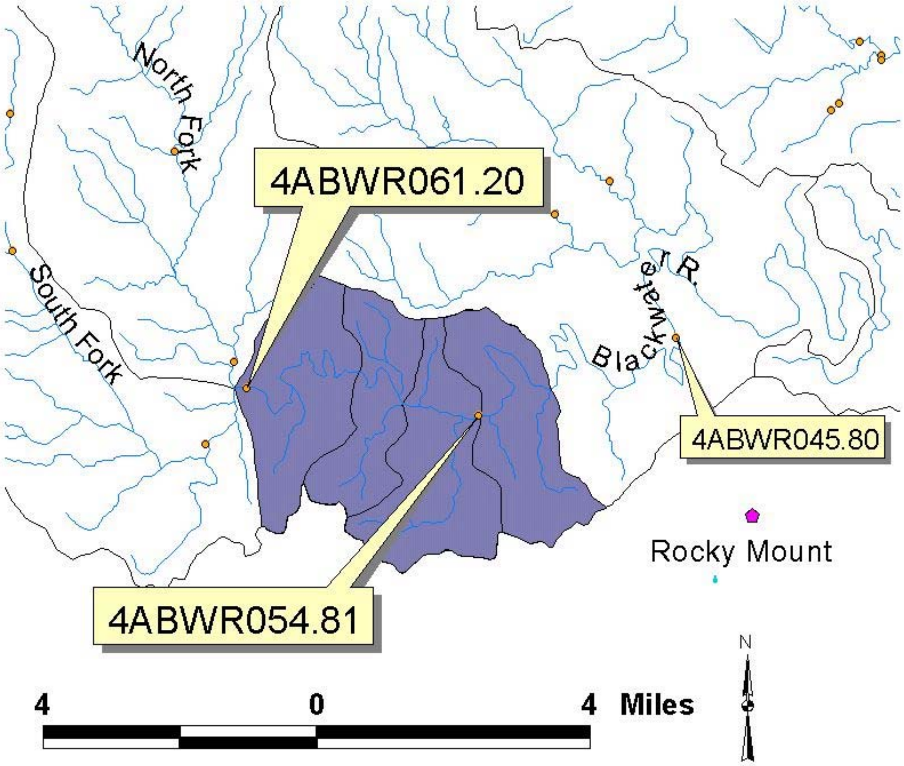

Figure 2.2 Location of water quality monitoring stations in the Upper Blackwater watershed.

2.2.1.2 Water Quality Monitoring Conducted by MapTech.

As a part of the services provided by MapTech to VADCR, water quality monitoring was performed on three days (9/21/99, 10/20/99, and 12/9/99) during the contracted period. Specifically, water quality samples were taken at 2 sites in the Upper Blackwater impairment. These samples were analyzed for fecal coliform concentrations and for fecal type by the Laboratory for Soil Microbiology in the Crop and Soil Environmental Science Department at Virginia Tech. Table 2.2 summarizes the fecal coliform concentration data collected by MapTech. Bacteria source tracking is discussed in greater detail in Section 2.2.2.2. Three of the four impairments exhibited violations of the 1,000 cfu/100 ml instantaneous standard in excess of 10%. In conjunction with the data collected by VADEQ and Ferrum College, the observance of 0% violations in the Middle Blackwater stations reflects the seasonal nature of the problem.

Table 2.2 Summary of water quality sampling conducted by MapTech. Fecal coliform concentrations (cfu/100 ml).

Impairment and Station Number	Count (#)	Minimum (cfu/100 ml)	Maximum (cfu/100 ml)	Mean (cfu/100 ml)	Median (cfu/100 ml)	Violations (%)
South Fork						
4AGCR002.44	3	30	1,070	680	940	33%
4ABSF001.15	3	280	10,000	3,643	650	33%
North Fork						
4ABNR009.36	3	40	260	140	120	0%
4ABNR000.40	3	320	49,000	19,773	10,000	67%
Upper Blackwater						
4ABWR061.20	**3**	**530**	**29,000**	**10,310**	**1,400**	**67%**
4ABWR054.81	**3**	**460**	**2,100**	**1,243**	**1,170**	**67%**
Middle Blackwater						
4ABWR045.80	3	270	760	463	360	0%
4ATEL001.02	3	30	490	260	260	0%
4ABWR032.32	3	40	250	140	130	0%

2.2.1.3 Ferrum College Study

Data collected as part of the *Blackwater River Riparian NPS Pollution Control Project* (MapTech, 1999a) were considered in examining the distribution of fecal coliform concentrations in the watershed. Table 2.3 summarizes the water quality data collected during the study. Results of this study were consistent with the results of VADEQ Monitoring.

Table 2.3 Summary of water quality sampling conducted as part of *the Preliminary Fecal Coliform Assessment in the Blackwater River* Watershed (Yagow et al., 1999).

Impairment	Count	Minimum	Maximum	Mean	Median	Violations
North Fork Blackwater	52	5	51,000	2,293	450	19%
Middle Blackwater	52	17	69,000	6,961	490	35%
Maggodee Creek	48	25	60,000	3,940	1,228	52%

2.2.1.4 Summary of In-stream Water Quality Monitoring Data

Because the data collected by MapTech and Ferrum College were not censored at 8,000 cfu/100 ml level, the maximum values provide insight into the potential concentrations of samples reported as 8,000 cfu/100 ml in the VADEQ data. Collins et al. (1996) reported a peak value of 160,000 cfu/100 ml for fecal coliform concentrations in uncensored samples taken in the Blackwater River Watershed, further indicating the potential for extreme values. Additionally, the mean values reported throughout tend to be higher than the median values indicating the existence of extreme high values.

2.2.2 Analysis of Water Quality Monitoring Data

The data collected were analyzed for frequency of violations, patterns in fecal source identification, and seasonal impacts. Results of the analyses are presented in the following sections.

2.2.2.1 Summary of Frequency of Violations at the Monitoring Stations

All water quality data were collected at a time-step of at least one month. The state standard of 1,000 cfu/100 ml was used to test for violations. Of the samples collected in the Upper Blackwater River, 82% were in violation of the state standard. A distribution of fecal coliform concentrations at each sampling station in the watershed can be found in Appendix A.

2.2.2.2 Bacteria Source Tracking

MapTech Inc. was contracted to do in-stream sampling and analysis of fecal coliform concentrations as well as bacteria source tracking. Bacteria source tracking is intended to aid in identifying sources (i.e. human, livestock, or wildlife) of fecal contamination in waterbodies. While the short time-frame available, and the subsequent small number of observations taken in this case makes drawing conclusions difficult, the data collected will be useful in setting a standard for the use of this technology in developing and implementing TMDLs. The information gained also provides insight into the likely sources of fecal contamination, and will improve the chances for success in implementing solutions.

Several procedures are currently under study for use in bacteria source tracking. The two being developed in Virginia that have shown promise include DNA fingerprinting and biochemical profiling using fecal streptococci. Both procedures are still very much experimental and no studies have yet been completed that compare the methods against each other. For this project, the biochemical profiling method was used to confirm the sources of fecal contamination in streams. This method was selected because it has been demonstrated to be a reliable procedure for confirming the presence or absence of human, livestock and wildlife sources in watersheds in Virginia. Compared to the DNA procedure, biochemical profiling is much quicker, typically analyzes many more isolates (e.g. 48 vs. 10 for DNA analysis), is generally less expensive, has survived limited court testing, and has undergone rigorous peer review from the academic community. The results of sampling were reported as the percentage of isolates acquired from the sample that were identified as originating from either human, livestock, or wildlife sources.

Figure 2.3 shows the relationship between fecal coliform concentration at the time of sampling and the percentage of isolates from each source. Results of monitoring in all

Blackwater River impairments are shown for comparative purposes. Due to the time constraints of the contract, an assessment of seasonal impacts could not be performed on these data.

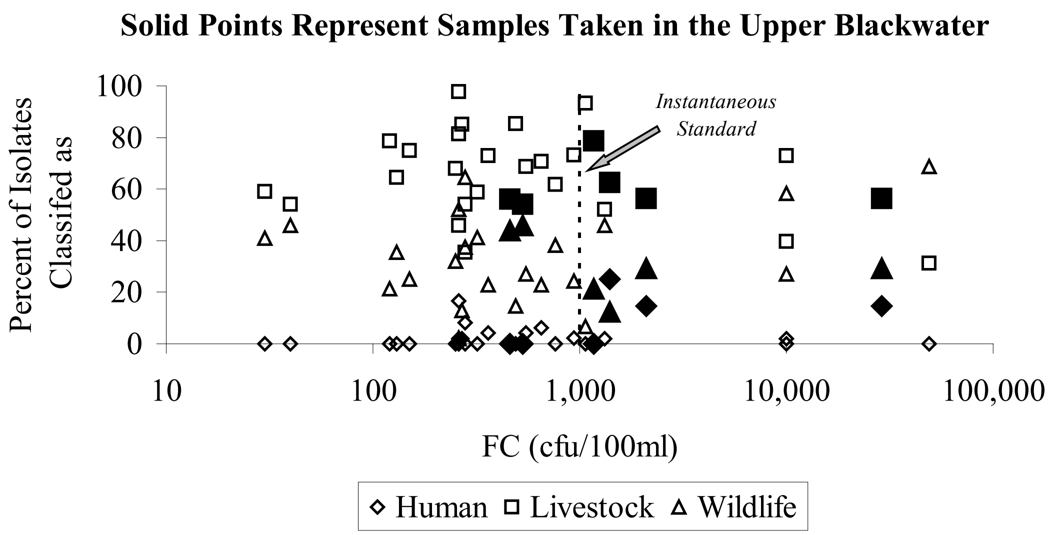

Figure 2.3 Results of MapTech's in-stream monitoring for fecal coliform concentrations and fecal sources.

2.2.2.3 Trend and Seasonal Analyses

In order to improve TMDL allocation scenarios and, therefore, the success of implementation strategies, trend and seasonal analyses were performed on precipitation, discharge, and fecal coliform concentrations. A Seasonal Kendall Test was used to examine long-term trends. The Seasonal Kendall Test ignores seasonal cycles when looking for long-term trends. This improves the chances of finding existing trends in data that are likely to have seasonal patterns. Additionally, trends for specific seasons can be analyzed. For instance, the Seasonal Kendall Test could identify the trend (over many years) in discharge levels during a particular season or month.

A seasonal analysis of precipitation, discharge, and fecal coliform concentration data was conducted using the Mood Median Test. This test was used to compare median values of precipitation, discharge, and fecal coliform concentrations in each month. Significant differences between months were reported.

2.2.2.3.1 Precipitation

Total Monthly precipitation measured at Rocky Mt., Virginia from 10/78 to 9/99, was analyzed, and no overall, long-term trend was found. However, for the month of January, a slight upward trend was detected from year to year. The slope of the increase in monthly precipitation for January was estimated at 0.16 in/year. The p-value calculated for this test was 0.08, indicating a high level of significance. No significant difference in monthly precipitation within years was detected.

2.2.2.3.2 Discharge

Mean monthly discharge measured at USGS Gauging Station #02056900 from 10/1/76 to 9/30/98, was analyzed, and an overall, long-term increase in discharge was observed. The slope of the increase in mean monthly discharge was estimated at 0.727 cfs/year. The p-value calculated for this test was 0.011, indicating a high level of significance. Much of this overall trend is likely due to an increasing trend for the months of January and February. The slope of the increase in mean monthly discharge for January and February was estimated at 3.69 and 4.21 cfs/year, respectively. The p-values calculated for both of these tests were 0.02, indicating a high level of significance. Differences in mean monthly discharge are indicated in Table 2.4. Discharges in months with the same median group letter are not significantly different from each other at the 95% significance level. For example, January, May, June, November, and December are all in median group "C" and are not significantly different from each other. In general, discharges in the summer-fall months tend to be lower than discharges in the winter-spring months, with September and October tending to have the lowest flows and March having the highest.

Table 2.4 Summary of Moods Median Test on mean monthly discharge at USGS Station #02056900.

Month	Mean	Minimum	Maximum	Median Groups[1]				
January	118.4	46.0	185.0			C		E
February	140.5	53.0	326.5				D	E
March	173.3	57.0	418.0					E
April	168.8	64.5	432.0				D	E
May	127.6	42.0	320.0			C	D	E
June	98.6	29.5	243.0		B	C	D	
July	66.1	20.0	156.0	A	B			
August	51.0	10.0	91.0	A	B			
September	56.9	18.0	151.0	A				
October	72.3	19.0	260.0	A				
November	84.7	27.5	204.5	A	B	C	D	
December	98.4	46.0	192.0		B	C	D	E

[1] Discharges in months with the same median group letter are not significantly different from each other at the 95% level of significance.

2.2.2.3.3 Fecal Coliform Concentrations

Water quality monitoring data collected by VADEQ were described in an earlier section (Section 2.2.1.1). The trend analysis was conducted on data collected at each station in the Upper Blackwater drainage area. A decreasing overall trend was detected at station 4ABWR061.20, with a slope of -340 CFU/100-ml/month. A p-value of 0.043 indicates a high level of significance. The decreasing overall trend at station 4ABWR061.20 may be largely due to a decreasing trend for the month of June. The slope of the trend is -666.67 CFU/100-ml/year, with a p-value of 0.06. This decreasing trend indicates an improvement in the problem for this station.

The analysis of seasonality was conducted using all data collected in the Blackwater River watershed. Mean monthly fecal coliform concentrations are indicated in Table 2.5. In general, concentrations in the winter months tend to be lower than concentrations in the summer months, with February and March tending to have the lowest concentrations and July having the highest. Considering these results in combination with the seasonal analysis of discharge, it appears that the highest concentrations are not associated with either the highest or the lowest mean discharges. Specifically, the highest concentrations tend to lead the lowest mean discharges by one to two months. This relationship suggests that the sources of fecal contamination are a combination of direct deposition to the stream and loadings transported to the stream by runoff. Additionally, the effect of die-off and regrowth in the land and stream environment has not been quantified and further complicates any analysis.

Table 2.5 Summary of Moods Median Test on mean monthly fecal coliform concentrations measured in the Blackwater River watershed.

Month	Mean	Minimum	Maximum	Median Groups[1]					
January	1,176	100	8,000	A	B				
February	1,251	100	8,000	A					
March	1,660	100	8,000	A					
April	1,371	100	8,000		B	C			
May	2,403	100	8,000			C	D		
June	2,620	100	8,000					E	F
July	2,925	100	8,000						F
August	2,144	100	8,000				D	E	
September	1,758	100	8,000			C	D		
October	1,358	100	8,000	A	B				
November	1,587	100	8,000	A	B	C	D		
December	1,638	100	8,000	A	B				

[1] Discharges in months with the same median group letter are not significantly different from each other at the 95% level of significance.

3. SOURCE ASSESSMENT

The TMDL development described in this report included examination of all potential sources of fecal coliform in the Upper Blackwater watershed. The source assessment was used as the basis of model development and ultimate analysis of TMDL allocation options. In evaluation of the sources, loads were characterized by the best available information, landowner input, literature values, and local management agencies. This section documents the available information and interpretation for the analysis. The source assessment chapter is organized into point and nonpoint sections. The representation of the following sources in the model is discussed in Section 4.

3.1 Assessment of Point Sources

Six point sources are permitted to discharge in the Black Water River watershed through the Virginia Pollutant Discharge Elimination System (VPDES). Figure 3.1 shows their discharge locations. None of these permitted point discharges is in the Upper Blackwater drainage area.

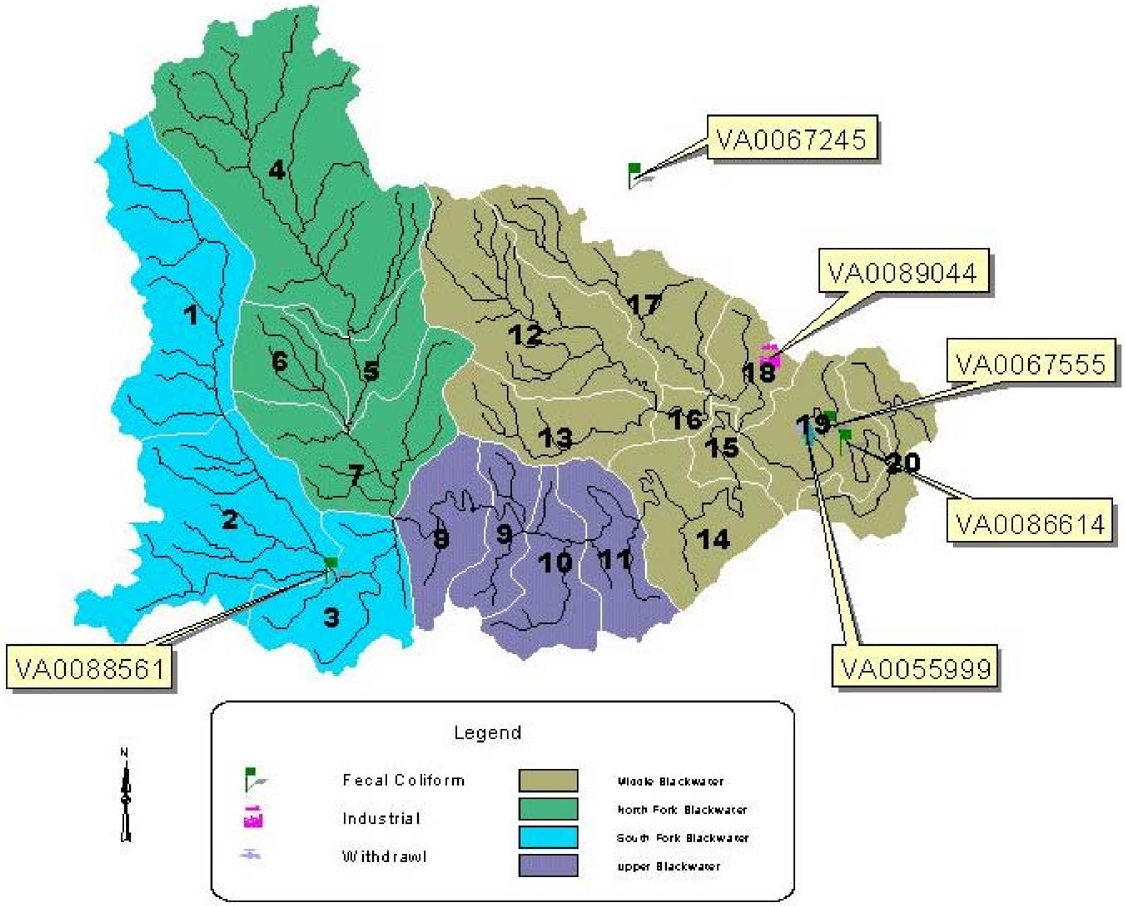

Figure 3.1 Location of VPDES permitted point sources in the Blackwater River watershed.

3.2 Assessment of Nonpoint Sources

In the Upper Blackwater watershed, both urban and rural nonpoint sources of fecal coliform bacteria were considered. Sources include residential sewage treatment systems, land application of waste (livestock and biosolids), livestock, wildlife, and pets. Sources were identified and enumerated. MapTech collected samples of fecal coliform sources (i.e. wildlife, livestock, and human waste) and enumerated the density of fecal coliform bacteria to support the modeling process, and expand the database of known fecal coliform sources for purposes of bacteria source tracking (Section 2.2.2.2). Where appropriate, spatial distribution of sources was also determined.

3.2.1 Private Residential Sewage Treatment

Typical private residential sewage treatment systems (septic systems) consist of a septic tank, distribution box, and a drainage field. Waste from the household flows first to the septic tank, where solids settle out and are periodically removed by a septic tank pump-out. The liquid portion of the waste (effluent) flows to the distribution box, where it is distributed among several buried, perforated pipes that comprise the drainage field. Once in the soil, the effluent flows downward to groundwater, laterally to surface water, and/or upward to the soil surface. Removal of fecal coliform is accomplished primarily by die-off during the time between introduction to the septic system and eventual introduction to naturally occurring waters. Properly designed, installed, and functioning septic systems that are more than 50 feet from a stream contribute virtually no fecal coliform to surface waters. Reneau (2000) reported that a very small portion of fecal coliform can survive in the soil system for over 50 days. This number might be higher or lower depending on soil moisture and temperature. An analysis of soil system hydrology for soils typical of the area revealed that lateral movement of 50 feet in 50 days would not be unusual. Based on this analysis, it was estimated that properly functioning septic systems within 50 feet of a stream contribute, on average, 0.001% of fecal coliform production. According to 1990 Census data for Franklin County, there were 14,267 septic systems in operation in the county (FCBS, 1995).

A septic failure occurs when a drain field has inadequate drainage or a "break", such that effluent flows directly to the soil surface, bypassing travel through the soil profile. In this situation the effluent is either available to be washed into waterways during runoff events or is directly deposited in stream due to proximity. A permit from the Virginia Department of Health (VDH) is required for installing or repairing a septic system. VDH reported 186 permits issued in the first 9 months of 1999 for repairs to septic systems. Based on this, 248 total permits were projected for 1999. Baker (2000) reported that this number could be increased by 5% to account for unreported failures. A survey of local septic pump-out contractors performed by MapTech showed that failures were more likely to occur in the winter-spring months than in the summer-fall months, and that a higher percentage of system failures were reported because of a back-up to the household than because of a failure noticed in the yard.

The 1990 Census (USCB, 1990) reports three categories of sewage treatment; public sewage treatment systems, private sewage treatment systems, and "other." "Other" includes portable toilets, latrines, and direct discharge of waste. The “other” category accounted for approximately 4% of the households in Franklin County. Additionally, the *1995 Comprehensive Plan* for Franklin County (FCBS, 1995) reports that approximately 2.5% of households lack complete plumbing (i.e. hot and cold water, flush toilet, and bathtub/shower). Baker (1999) reported that 0.5% of the number of private sewage systems was a good estimate for the number of households directly depositing sewage to streams.

MapTech (1999) sampled waste from septic tank pump-outs in the watershed and found an average fecal coliform density of 287,900 cfu/100 ml. Geldreich (1978) reported an average fecal coliform density for human waste of 13,000,000 cfu/100 ml and a total waste load (including gray water) of 75 gal/day/person.

3.2.2 Livestock

The predominant types of livestock in the Blackwater River Watershed are dairy and beef cattle, although all types of livestock identified were considered in modeling the watershed. Animal populations were based on a 1998 livestock inventory performed in the *Blackwater River Riparian NPS Pollution Control Project* (MapTech, 1999a) by Ferrum College, watershed visits, and verbal communication with farmers. In the inventory, each farm was assigned an index number with the breakdown of animals associated with that farm. The inventory was updated to 1999 conditions by accounting for such things as farms going out of business, herd size differences, animal type changes, and new farms and animals. Table 3.1 depicts a partial listing of information contained in the livestock inventory. The inventory also included information regarding the management of livestock (e.g. time in loafing lot, percentage of waste collected, etc.).

Table 3.2 gives a summary of livestock populations in the Blackwater River Watershed. Values of fecal coliform density of livestock sources were based on sampling done in the watershed by MapTech. Reported manure production rates for livestock were taken from ASAE, 1998. A summary of fecal coliform density values and manure production rates is presented in Table 3.3.

Table 3.1 Partial listing of information contained in livestock inventory of Blackwater Riparian NPS Pollution Control Project.

Livestock Site Map Index Code	Number of Animals	Average Weight (lb)	Time in Loafing Lot (hrs)	Waste Collected (%)	Stream Access (hrs)	Collected Waste Spread (%)	Time on Farm (months)	Loafing Area (ac)	Animal Type
1	75	1,350	24	75	0	100	12	8	dairy
2	76	1,350	24	50	12	100	12	6	dairy
3	78	1,350	24	33	0	100	12	12	dairy
*	*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*
216	7	1,050	0	0	1.2	0	12	0	beef
217	6	250	0	0	1.2	0	9	0	beef
218	100	1,350	0	0	1.2	0	12	0	dairy
219	100	500	0	0	1.2	0	12	0	dairy

Table 3.2 Livestock populations in the Upper Blackwater watershed

Animal Type	Number of Animals
Dairy	3,489
Beef	354
Horse	1
Donkey	0
Sheep	0
Goat	0

Table 3.3 Average fecal coliform densities and waste loads associated with livestock

Type	Waste Load (lb/d/an)	FC Density (FC/gm)
Dairy (1,400 lb)	120.4	427,667
Beef (800 lb)	46.4	45,500
Horse (1,000 lb)	51.0	185,000
Donkey	51.0	185,000 [1]
Sheep (60 lb)	2.4	15,000
Goat	5.7	15,000 [2]
Dairy Separator	N/A	32,000
Dairy Storage Pit	N/A	1,200 [3]

[1] Fecal coliform density for donkey feces was assumed to be equal to that of horse.
[2] Fecal coliform density for goat feces was assumed to be equal to that of sheep.
[3] Units are cfu/100ml.

Fecal coliform produced by livestock can enter surface waters through four pathways. First, waste produced by animals in confinement is typically collected, stored, and applied to the landscape (e.g. pasture and cropland), where it is available for wash-off during a runoff-producing rainfall event. Second, grazing livestock deposit manure directly on the land, where it is available for wash-off during a runoff-producing rainfall event. Third, livestock with access to streams occasionally deposit manure directly in streams. And fourth, some animal confinement facilities have drainage systems that divert wash-water and waste directly to drainage ways or streams.

Dairy production is the primary source of land-applied livestock waste. Only one beef producer was identified as collecting and applying a portion of the beef cattle waste produced on the farm. This producer also operated a dairy and the collected beef cattle waste was stored in a common pit with the dairy cattle waste. The additional waste collected was considered. However, all land-applied livestock waste was treated as dairy cattle waste in terms of the amount of fecal coliform bacteria expected. Time in confinement was taken from data reported in the *Blackwater River Riparian NPS Pollution Control Project* (Table 3.1). Average values from a farmer survey conducted by MapTech on 11/22/99 were used where numbers were not available for individual farms (Table 3.4). This survey also provided estimates of the timing of applications throughout the year (Table 3.5).

Table 3.4 Average time dairy cows spend in different areas per day. Based on farmer survey, 11/22/99.

Month	Pasture (hr)	Stream Access (hr)	Loafing Lot - Confinement (hr)
January	7.2	0.5	16.3
February	7.2	0.5	16.3
March	7.6	1.0	15.4
April	8.6	1.5	13.9
May	9.3	1.5	13.2
June	9.3	2.0	12.7
July	9.8	2.0	12.2
August	9.8	2.0	12.2
September	10.3	1.5	12.2
October	10.5	1.0	12.5
November	9.8	1.0	13.2
December	8.9	0.5	14.6

Table 3.5 Average percentage of collected waste applied throughout year.

Month	Pasture (%)	Cropland (%)
January	0.00	1.50
February	0.00	1.75
March	0.00	17.00
April	0.00	17.00
May	0.00	17.00
June	1.75	0.00
July	1.75	0.00
August	1.75	0.00
September	0.00	5.00
October	0.00	17.00
November	0.00	17.00
December	0.00	1.50

All livestock were expected to deposit some portion of waste on land areas. The percentage of time spent on pasture for dairy and beef cattle was reported by the *Blackwater River Riparian NPS Pollution Control Project* (Table 3.1). Average values from a farmer survey conducted on 11/22/99 were used where numbers were not available for individual farms. The percentage of time spent in pasture by dairy cattle is reported in Table 3.4. The percentage of time spent in pasture by beef cattle is reported in Table 3.6. Horses, sheep, donkeys, and goats were assumed to be in pasture 100% of the time.

Only dairy and beef cattle were expected to make a significant contribution through direct deposition to streams. The average amount of time spent by dairy and beef cattle in close proximity to streams for each month is given in Table 3.4 and Table 3.6, respectively.

Table 3.6 Average time beef cows spend in different areas per day.

Month	Pasture (hr)	Stream Access (hr)	Loafing Lot (hr)
January	23.0	1.0	0
February	23.0	1.0	0
March	22.5	1.5	0
April	22.0	2.0	0
May	22.0	2.0	0
June	21.5	2.5	0
July	21.5	2.5	0
August	21.5	2.5	0
September	22.0	2.0	0
October	22.5	1.5	0
November	22.5	1.5	0
December	23.0	1.0	0

3.2.3 Biosolids

Biosolids produced at the Roanoke Waste Water Treatment Plant (RWWTP) and the Upper Smith River Waste Water Treatment Plant (USRWWTP) are applied to agricultural lands in Franklin County. In 1996, approximately 652.5 acres received biosolids applications in Franklin County. No applications occurred in the Upper Blackwater watershed from 1994 to 1998. The application of biosolids to agricultural lands is strictly regulated in Virginia (VDH, 1997). Biosolids are required to be spread according to sound agronomic requirements, and consideration for topography and hydrology. Class B biosolids may not have a fecal coliform density greater than 1,995,262 cfu/g (total solids). And, application rates must be limited to a maximum of 15 dry tons/ac per three-year period. Average fecal coliform densities measured were 101 cfu/g (total solids) (MapTech, 1999b) and 68,467 cfu/g (total solids) (DEQ, 2000) for

RWWTP and USRWWTP, respectively. The average application rate in Franklin County is 6.76 dry tons/ac (DEQ, 2000) where applied.

3.2.4 Wildlife

The predominant wildlife species in the watershed were determined through consultation with wildlife biologists from the Virginia Department of Game and Inland Fisheries (VDGIF), citizens from the watershed, faculty at Ferrum College, source sampling, and site visits. Population densities were provided by VDGIF and are listed in Table 3.7 (Farrar,2000; Keeling, 2000; Knox, 1999; Costanzo, 1999; Norman and Lafon, 1998; and Rose and Cranford, 1987). The numbers of animals estimated to be in the Upper Blackwater watershed are reported in Table 3.8. Habitat and seasonal food preferences were determined based on information obtained from The Fire Effects Information System (1999) and VDGIF (Costanzo, 2000; Norman, 1999; Rose and Cranford, 1987; and VDGIF, 1999). Waste loads were comprised from literature values and discussion with VDGIF personnel (ASAE, 1998; Costanzo, 2000; Weiskel et al., 1998, and Yagow, 1999). Table 3.9 summarizes the habitat and fecal production information that was obtained. Where available, fecal coliform densities were based on sampling of wildlife waste done in the watershed by MapTech. The only value that was not obtained from sampling in the watershed was for beaver. The fecal coliform density of beaver waste was taken from sampling done for the Mountain Run TMDL development (Yagow, 1999). Percentage of waste directly deposited to streams was based on habitat information that was collected and location of feces during source sampling. Fecal Coliform densities and estimated percentages of time spent in stream access areas are reported in Table 3.10.

Table 3.7 Wildlife population density.

Animal	Density	Density Unit
Raccoon	0.070	an/ac of habitat
Muskrat	2.750	an/ac of habitat
Beaver	4.800	an/mi of stream
Deer	0.047	an/ac of habitat
Turkey	0.010	an/ac of forest
Goose	0.004	an/ac
Mallard	0.002	an/ac

Table 3.8 Wildlife populations in the Upper Blackwater watershed.

Species	Number of Animals
Raccoon	122
Muskrat	763
Beaver	50
Deer	457
Turkey	90
Goose	39
Mallard	20

Table 3.9 Wildlife fecal production rates and habitat.

Animal	Waste Load (gm/an/day)	Habitat
Raccoon	450	Primary = region within 600 ft of stream and ponds Less frequent = region between 601 and 7,920 ft
Muskrat	100	Continuous flowing stream below 1,300 ft elevation; Primary = region within 66 ft of stream and ponds Less frequent = region between 67 and 300 ft
Beaver[1]	200	Continuous flowing stream below 1,300 ft elevation; Primary = region within 300 ft of stream and ponds Less frequent = region between 301 and 656 ft
Deer	772	All area of the watershed
Turkey[2]	320	All area of watershed excluding farmsteads and urban land uses
Goose[3]	225	Continuous flowing stream below 1,300 ft elevation; Primary = region within 66 ft of stream and ponds Less frequent = region between 67 and 300 ft
Mallard	150	Continuous flowing stream below 1,300 ft elevation; Primary = region within 66 ft of stream and ponds Less frequent = region between 67 and 300 ft

1 Beaver waste load was calculated as twice that of muskrat, based on field observations.
2 Waste load for domestic turkey (ASAE, 1998).
3 Goose waste load was calculated as 50% greater than that of duck, based on field observations and conversation with Gary Costanzo (Costanzo, 2000).

Table 3.10 Average fecal coliform densities and percentage of time spent in stream access areas for wildlife.

Type	Fecal Coliform Density (FC/gm)	Direct Deposition (%)
Raccoon	13,100,000	5
Muskrat	1,900,000	90
Beaver	1,000	100
Deer	3,300,000	5
Turkey	1,332	5
Goose	320	50
Duck	490	75

3.2.5 Pets

Among pets, cats and dogs are the predominant contributors of fecal coliform in the watershed and were the only pets considered in this analysis. Cat and dog populations were derived from Lehigh Valley Animal Rights Coalition for United States averages in 1996. Dog waste load was reported by Weiskel et al. (1996), while cat waste load was measured. Fecal coliform density for dogs and cats was measured from samples collected in the watershed by MapTech. A summary of the data collected is given in Table 3.11.

Table 3.11 Domestic animal population density, waste load, and fecal coliform density.

Type	Population Density (an/house)	Waste load (gm/an-day)	FC Density (FC/gm)
Dog	1.7	450	2,200,000
Cat	2.2	19.4	26

4. MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between in-stream water quality and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. In the development of a TMDL for the Upper Blackwater watershed, the relationship was defined through computer modeling based on data collected throughout the watershed. Monitored flow and water quality data were then used to verify that the relationships developed through modeling were accurate. In this section, the selection of modeling tools, parameter development, calibration/validation, and model application are discussed.

4.1 Modeling Framework Selection

The USGS Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate existing conditions and to perform TMDL allocations. The HSPF model is a continuous simulation model that can account for NPS pollutants in runoff, as well as pollutants entering the flow channel from point sources. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities were explicitly accounted for in the model. The use of HSPF allowed consideration of seasonal aspects of precipitation patterns within the watershed.

The stream segment within each subwatershed is simulated as a single reach of open channel, referred to as a RCHRES. Water and pollutants from the land segments (PERLNDs and IMPLNDs) are transported to the RCHRES using mass links. Mass links are also used to connect the modeled RCHRES segments in the same configuration the real stream segments are found in the physical world. The same mass link principal is applied when water and pollutants are conveyed to a RCHRES via a point discharge, or water is withdrawn from a particular RCHRES. On a larger scale, impaired stream segments are also linked to one another by mass links. Therefore, activities simulated in one impaired stream segment affect the water quality downstream in the model.

4.2 Model Setup

To adequately represent the spatial variation in the watershed, the Upper Blackwater drainage area was divided into four subwatersheds. The rationale for choosing these subwatersheds was based on the availability of water quality data and the limitations of the HSPF model. Water quality data (i.e. fecal coliform concentrations) are available at specific locations throughout the watershed. Subwatershed outlets were chosen to coincide with these monitoring stations, since output from the model can only be obtained at the modeled subwatershed outlets (Table 4.1). The HSPF model requires that the time of concentration in any subwatershed be greater than the time-step being used for the model. Given this modeling constraint and the desire to maintain a spatial distribution of watershed characteristics and associated parameters, a 15-minute modeling time-step was determined to be required. The spatial division of the watershed allowed for a more refined representation of pollutant sources, and a more realistic description of hydrologic factors in the watershed.

Table 4.1 VADEQ monitoring stations and corresponding reaches in the Upper Blackwater watershed.

Station Number	Reach Number
4ABWR061.20	10
4ABWR054.81	11

Within each subwatershed, up to 8 land use types were represented. Each land use had parameters associated with it that described the hydrology of the area (e.g. average slope length) and the behavior of pollutants (e.g. fecal coliform accumulation rate). Table 4.2 shows the different land use types and the area existing in each subwatershed. These land use types are represented in HSPF as pervious land segments (PERLNDs) and impervious land segments (IMPLNDs). All of the impervious areas in the watershed are represented in one IMPLND type, while there are eight PERLND types, each with parameters describing a particular land use. Some IMPLND and PERLND parameters (e.g. slope length) vary with the particular subwatershed in which they are located. Others vary with season (e.g. upper zone storage) to account for plant growth, die-off, and removal.

Table 4.2 Spatial distribution of land use types in the Upper Blackwater drainage area.

Land Use	Acreage
Good Pasture	1,183
Poor Pasture	474
Cropland	3,217
Forest	4,423
Urban	307
Farmsteads	45
Livestock Access to Streams	70
Loafing Area	26

Die-off of fecal coliform can be handled implicitly or explicitly. For land-applied fecal matter, (mechanically applied and deposited directly) die-off was addressed implicitly through monitoring and modeling. Samples of collected waste (i.e. dairy waste from loafing areas) were locally collected and analyzed prior to land application. Therefore, die-off is implicitly accounted for through the sample analysis. Die-off occurring in the field was represented implicitly through model parameters such as the maximum accumulation and the 90% wash off rate, which were adjusted during the calibration of the model. These parameters were assumed to represent not only the delivery mechanisms but the bacteria die-off as well. Once the fecal coliform entered the stream, the general decay module of HSPF was incorporated, thereby explicitly addressing the die-off rate. The general decay module uses a first order decay function to simulate die-off.

4.3 Source Representation

Both point and nonpoint sources can be represented in the model. In general, point sources are added to the model as a time-series of pollutant and flow inputs to the stream. Land-based nonpoint sources are represented as an accumulation of pollutants on land, where some portion is available for transport in runoff. The amount of accumulation and availability for transport vary with land use type and season. The model allows for a maximum accumulation to be specified. The maximum accumulation was adjusted seasonally to account for changes in die-off rates, which are dependent on temperature and moisture conditions. Some nonpoint sources, rather than being land-based, are represented as being deposited directly to the stream (e.g. animal defecation in stream). These sources are modeled similarly to point sources, as they do not require a runoff event for delivery to the stream. These sources are primarily due to animal activity, which varies with the time of day. Direct depositions by nocturnal animals were modeled as being deposited from 6:00 PM to 6:00 AM, and direct depositions by diurnal animals were modeled as being deposited from 6:00 AM to 6:00 PM. Once in stream, die-off is represented by a first-order exponential equation.

Much of the data used to develop the model inputs for modeling water quality is time-dependent (e.g. population). Depending on the timeframe of the simulation being run, different numbers should be used. Data representing 1994 were used for the water quality calibration and validation period (1991-1995). Data representing 1999 were used for the allocation runs in order to represent current conditions. Additionally, data projected to 2004 were analyzed to assess the impact of changing populations.

4.3.1 Point Sources

There are no permitted point discharges in the Upper Blackwater drainage area. No point discharges were modeled, however, nonpoint sources of pollution that were not driven by runoff (e.g. direct deposition of fecal matter to the stream by wildlife) were modeled simmilarly to point sources. These sources as well as land based sources are identified in the following sections.

4.3.2 Private Residential Sewage Treatment

The number of septic systems in the four subwatersheds modeled for the Upper Blackwater watershed were calculated by overlaying 1990 Census group-block and block data (USCB, 1990) with the watershed to enumerate the households. These numbers were projected to 1994, 1999, and 2004 using the growth rate for Franklin County (FCBS, 1995). Households were then distributed among farmstead and urban land-use types. The total number of households, reported by the 1990 Census, included farmsteads, which were assumed to have septic systems. Ferrum College (MapTech,

1999) reported the number and location of farmsteads in the watershed. Each farmstead land-use area was assigned a number of septic systems based on this data. Of the remaining households, only a percentage was reported to be on private sewage (septic) systems (FCBS, 1995). These households were assigned to the urban land-use type. A total of 269 septic systems was estimated in the Upper Blackwater watershed in 1994. During allocation runs, the number of households was projected to 1999, based on current Franklin County growth rates (FCBS, 1995) resulting in 340 septic systems. The number of septic systems is projected to increase to 351 by 2004.

4.3.2.1 Functional Septic Systems

Using a procedure developed by MapTech, 1990 Census data (USCB, 1990), overlaid with urban land use and hydrography maps of the watershed, were analyzed to determine the percentage of households with septic systems that were located within 50 feet of a stream. This number was then projected to 1994, 1999, and 2004. The resulting numbers of septic systems within 50 feet of a stream were 17, 22, and 22, respectively. It was assumed for these homes that 0.001% of the fecal coliform produced in the household would reach the stream through lateral flow. The average number of people per household in each of the four subwatersheds was used to determine the waste load from each house, and the values reported in Section 3.2.1 for human waste load and fecal coliform density were used to determine the fecal coliform load.

4.3.2.2 Failing Septic Systems

Failing septic systems were assumed to deliver all effluent to the soil surface where it was available for wash-off during a runoff event. The number of permits issued in Franklin County by VDH for repairs in 1999 was divided by the number of septic systems in the county to determine the percentage of septic failures. A comparable failure rate was determined from a survey conducted by MapTech of Franklin County septic pump-out contractors. The survey also indicated that the majority of failures occurred at homes that were over 20 years old. The total number of failing septic systems in the watershed was therefore distributed among subwatersheds based on the number of homes over 20 years old. The fecal coliform density for septic system effluent was multiplied by the average design load for the septic systems in the subwatershed to determine the total load from each failing system. Additionally, the loads were distributed seasonally based on the survey of septic pump-out contractors to account for more frequent failures during wet months.

4.3.2.3 Uncontrolled Discharges

The number of uncontrolled discharges was estimated to be equal to 0.5% of the number of septic systems in the Upper Blackwater watershed (Section 3.2.1). Since older homes are more likely to have uncontrolled discharges, the number of uncontrolled discharges was distributed among subwatersheds based on the number of homes in each subwatershed that were built more than 30-years prior. Fecal coliform loads for each discharge were calculated based on the fecal density of human waste and the waste load for the average size household in the subwatershed. The loadings from uncontrolled discharges were applied directly to the stream in the same manner that point sources are handled in the model.

4.3.3 Livestock

Fecal coliform produced by livestock can enter surface waters through four pathways; land application of stored waste, deposition on land, direct deposition to streams, and diversion of wash-water and waste directly to streams. Each of these pathways is accounted for in the model. The number of fecal coliform directed through each pathway was calculated by multiplying the fecal coliform density with the amount of waste expected through that pathway. Livestock numbers determined for 1999 were used for the allocation runs, while these numbers were projected back to 1994 for the calibration and validation runs, based on Franklin County growth rates determined from data reported by the Virginia Agricultural Statistics Service (VASS, 1994; VASS, 1995; VASS, 1996; VASS, 1997; VASS, 1999). Similarly, when growth was analyzed, livestock numbers were projected to 2004. For land-applied waste, the fecal coliform density measured from waste storage pit effluent during land application was used, while the density in as-excreted manure was used to calculate the load for deposition on land and to streams (Table 3.3). The use of fecal coliform densities measured in pit-stored manure accounts for any die-off that occurs in storage. The modeling of fecal coliform entering the stream through diversion of wash-water was accounted for by the direct deposition of fecal matter to streams by cattle.

4.3.3.1 Land Application of Collected Manure

The only significant collection of livestock manure occurs on dairy farms. For each dairy farm in the drainage area, the average daily waste production per month was calculated using the number of cows, weight of animal, and waste production rate as reported in Section 3.2.2. The amount of waste collected was first based on proportion of milking cows, as the milking herd represented the only cows subject to confinement and therefore waste collection. Second, the total amount of waste produced in confinement was calculated based on the proportion of time spent in confinement. If beef cattle were confined for some percentage of time, the waste produced while in confinement was added to this total. Finally, values for the percentage of loafing lot waste collected, taken from the livestock inventory conducted by Ferrum College and reported by MapTech (1999), were used to calculate the amount of waste available to be spread on pasture and cropland (Table 3.1). Average percentage of waste applied throughout the year for each land use reported in the farmer survey was used to distribute land-applied waste. It was assumed that 100% of land-applied waste is available for transport in surface runoff transport unless the waste is incorporated in the soil by plowing during seedbed preparation. Percentage of cropland plowed and amount of waste incorporated was adjusted using calibration for the months of planting.

4.3.3.2 Deposition on Land

For cattle, the amount of waste deposited on land per day was a proportion of the total waste produced per day. The proportion was calculated based on the livestock inventory conducted by Ferrum College and reported by MapTech (1999a). Where data availability was lacking, average values based on the farmer survey conducted on 11/22/99 were used. The proportion was based on the amount of time spent in pasture, but not in close proximity to accessible streams, and was calculated as follows:

Proportion = [(24 hr) – (time in confinement) – (time in stream access areas)]/(24 hr)

All other livestock (horse, sheep, donkey, and goat) were assumed to deposit all feces on pasture. Pasture land-use types were divided into good and poor pasture. The total amount of fecal matter deposited on each of these land-use types was area-weighted on a farm-by-farm basis.

4.3.3.3 Direct Deposition to Streams

Dairy and beef cattle are the primary sources of direct deposition by livestock in the Blackwater River watershed. The amount of waste deposited in streams each day was a proportion of the total waste produced per day by cattle. First, the proportion of manure deposited in "stream access" areas was calculated based on the livestock inventory conducted by Ferrum College and reported by MapTech (1999). Where data availability was lacking, average values based on the farmer survey conducted on 11-22-99 were used. The proportion was calculated as follows:

Proportion = (time in stream access areas)/(24 hr)

For the waste produced on the "stream access" land use, 70% of the waste was modeled as being directly deposited in the stream and 30% remained on the land segment adjacent to the stream. The 30% remaining was treated as manure deposited on land. However, applying it in a separate land-use area (stream access) allows the model to consider the proximity of the deposition to the stream. The 70% that was directly deposited to the stream was modeled in the same way that point sources are handled in the model.

4.3.4 Biosolids

While approximately 652.5 acres of land received biosolids applications in Franklin County in 1996. Investigation of VADEQ, VDH, and Whellabrator data indicated that no biosolids applications were recorded in the Upper Blackwater watershed during the assessment period that resulted in it being placed on the 303(d) List of Impaired Waters (Keeling, 1999; MapTech, 2000; Wheelabrator, 2000). For model calibration, no biosolids were modeled. With urban populations growing, the disposal of biosolids will take on increasing importance. Class B biosolids have been measured with 68,467 cfu/g-dry and are permitted to contain up to 1,995,262 cfu/g-dry, as compared with approximately 240 cfu/g-dry for dairy waste. The sensitivity analysis provided insight into the effects that increased applications of biosolids could have on water quality.

4.3.5 Wildlife

For each species, a GIS habitat layer was developed based on the habitat descriptions that were obtained (Section 3.2.4). An example of one of these layers is shown in Figure 4.1. This layer was overlaid with the land use layer and the resulting area was calculated for each land use in each subwatershed. The number of animals per land segment was determined by multiplying the area times the population density. Fecal coliform loads for each land segment were calculated by multiplying the waste load, fecal coliform densities, and number of animals for each species.

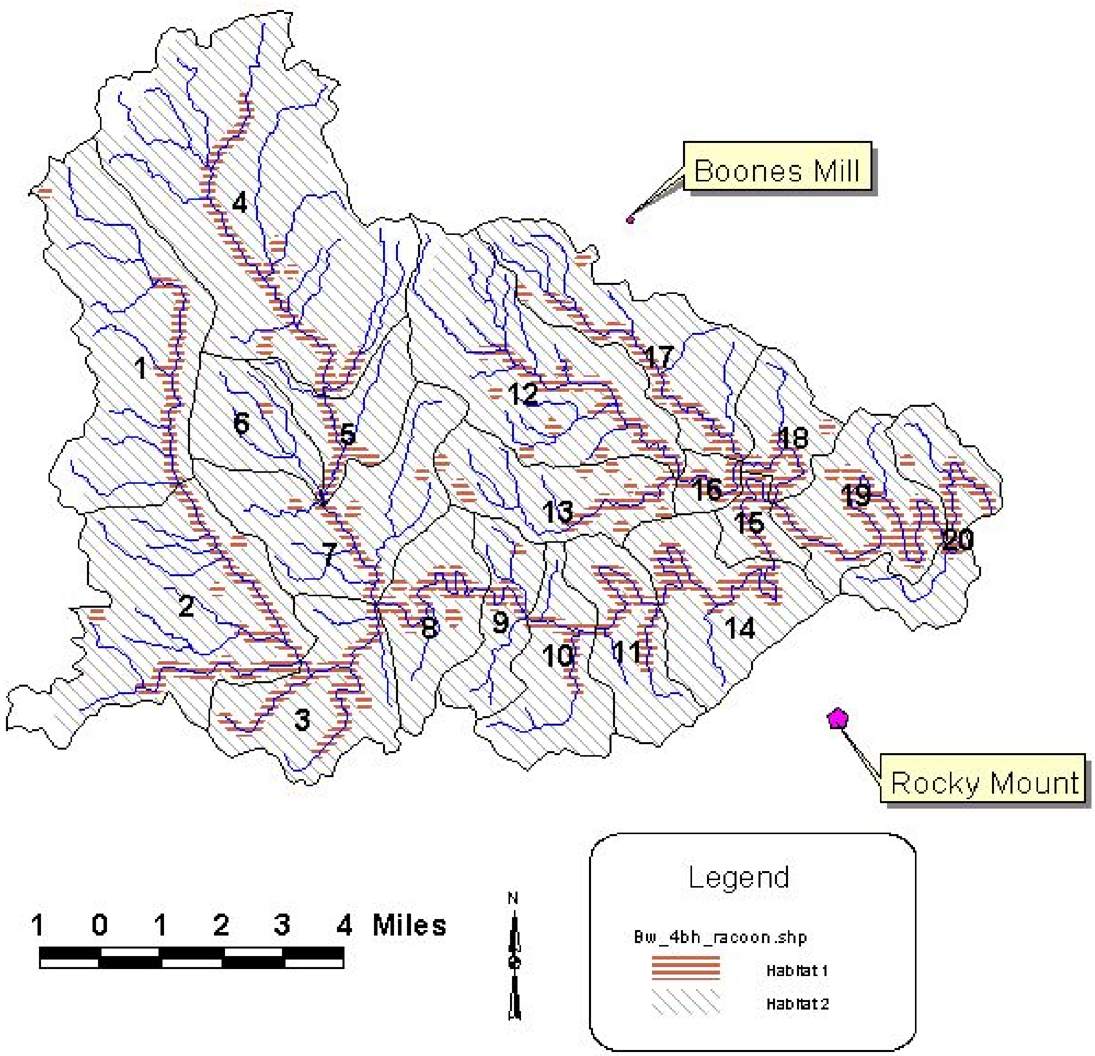

Figure 4.1 Example of habitat layer developed by MapTech (raccoon habitat in the Blackwater River watershed).

Seasonal distribution of waste was determined using seasonal food preferences for deer and turkey. Goose and duck populations were varied based on migration patterns. No seasonal variation was assumed for the remaining species. For each species, a portion of the total waste load was considered to be land-based, with the remaining portion being directly deposited to streams. The portion being deposited to streams was based on the amount of time spent in stream access areas (Table 3.10). It was estimated that for all animals other than beaver that 5% of fecal matter produced while in stream access areas was directly deposited to the stream. For beaver, it was estimated that 100% of fecal matter would be directly deposited to streams. To account for unquantifiable fecal coliform loads from known wildlife species, a background load was applied to all land segments at 10% of the total land-based wildlife load, and the total direct deposition wildlife load was increased by 10%. No long-term (1994 – 2004) adjustments were made to wildlife populations, as there was no available data to support such adjustments.

4.3.6 Pets

Cats and dogs were the only pets considered in this analysis. Population density (animals/house), waste load, and fecal coliform density are reported in Section 3.2.5. Waste from pets was distributed in the urban and farmstead land uses. The location of households was taken from the 1990 Census (USCB, 1990). The land use and household layers were overlaid which resulted in number of households per land use. The number of animals per land use was determined by multiplying the number of households by the population density. The amount of fecal coliform deposited daily by pets in each land use segment was calculated by multiplying the waste load, fecal coliform density, and number of animals for both cats and dogs. The waste load from pets was assumed not to vary seasonally. The populations of cats and dogs were projected from 1990 data to 1994, 1999, and 2004 based on human population growth rates.

4.4 Stream Characteristics

HSPF requires that each stream reach be represented by constant characteristics (e.g. stream geometry and resistance to flow). In order to determine a representative stream profile for each stream reach, cross-sections were surveyed at the subwatershed outlets. One outlet was considered the beginning of the next reach, when appropriate. In the case of a confluence, sections were surveyed above the confluence for each tributary and below the confluence on the main stream.

Most of the sections exhibited distinct flood plains with pitch and resistance to flow significantly different from that of the main channel slopes. The streambed, channel banks, and flood plains were identified. Once identified, the streambed width and slopes of channel banks and flood plains were calculated using the survey data. A representative stream profile for each surveyed cross-section was developed and consisted of a trapezoidal channel with pitch breaks at the beginning of the flood plain (Figure 4.2). With this approach, the flood plain can be represented differently from the streambed. To represent the entire reach, profile data collected at each end of the reach were averaged.

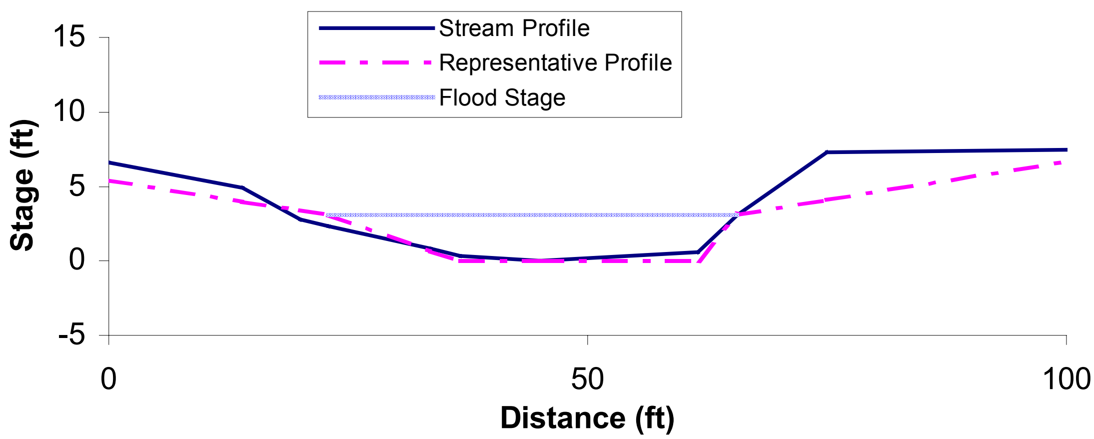

Figure 4.2 Stream profile representation in HSPF.

Conveyance was used to facilitate the calculation of discharge in the reach with different values for resistance to flow (Manning's n) assigned to the flood plains and streambeds. The conveyance was calculated for each of the two flood plains and the main channel, then added together to obtain a total conveyance. Calculation of conveyance was performed following the procedure described by Chow (1959). The total conveyance was then multiplied by the square root of the average reach slope to obtain the discharge (in ft^3/s) at a given depth.

A key parameter used in the calculation of conveyance is the Manning's roughness coefficient, n. There are many ways to estimate this parameter for a section. The method first introduced by Cowan (1956) and adopted by the Soil Conservation Service (1963) was used to estimate Manning's n. This procedure involves a 6-step process of evaluating the properties of the reach, which is explained in more detail by Chow (1959). Field data describing the channel bed, bank stability, vegetation, obstructions, and other pertinent parameters were collected. Photographs were also taken of the sections while in the field. Once the field data were collected, they were used to estimate the Manning's roughness for the section observed. The pictures were compared to pictures contained in Chow (1959) for validation of the estimates of the Manning's n for each section.

The result of the field inspections of the reach sections was a set of characteristic slopes (channel sides and field plains), bed widths, heights to flood plain, and Manning's roughness coefficients. Average reach slope and reach length were obtained from GIS layers of the watershed, which included elevation from Digital Elevation Models (DEMs) and a stream-flow network digitized from USGS 7.5-minute quadrangle maps (scale 1:24,000). These data were used to derive the Hydraulic Function Tables (F-tables) used by the HSPF model (Table 4.3). The F-tables developed consist of four columns; depth (ft), area (ac), volume (ac-ft), and outflow (ft^3/s). The depth represents the possible range of flow, with a maximum value beyond what would be expected for the reach. A maximum depth of 50 ft was used in the F-tables. The area listed is the surface area of the flow in acres. The volume corresponds to the total volume of the flow in the reach, and is reported in acre-feet. The outflow is simply the stream discharge, in cubic feet per second.

Table 4.3 Example of an "F-table" calculated for the HSPF Model.

Depth (ft)	Area (ac)	Volume (ac-ft)	Outflow (ft^3/s)
0.0	21.75	0.00	0.00
0.2	21.96	4.37	10.87
0.4	22.16	8.78	34.54
0.6	22.36	13.23	67.92
0.8	22.56	17.73	109.75
1.0	22.77	22.26	159.29
1.3	23.07	29.14	246.88
1.7	23.48	38.44	386.59
2.0	23.78	45.53	507.43
2.3	24.08	52.71	641.30
2.7	24.49	62.43	839.20
3.0	24.79	69.82	1,001.68
6.0	29.42	149.62	3,222.35
9.0	37.08	249.37	6,254.60
12.0	44.73	372.08	10,078.05
15.0	52.38	517.75	14,818.37
25.0	77.32	1163.48	38,629.43
50.0	92.02	2796.19	103,246.75

4.5 Selection of Representative Modeling Period

Selection of the modeling period was based on two factors; availability of data (discharge and water quality) and the need to represent critical hydrological conditions. Mean daily discharge data at USGS Gauging Station #02056900 were available from October 1976 to September 1998. Mean 30-minute discharge data (based on 15-minute instantaneous measurements) were available from October 1994 to June 1999. The most comprehensive time period for reported fecal coliform concentrations is during the assessment period from May 1991 to September 1995. The fecal coliform concentration data were evaluated for use during calibration and validation of the model. Calibration is the process of comparing modeled data to observed data and making appropriate adjustments to model parameters to minimize the error between observed and simulated events. Using observed data that is reported at a shorter time-step improves this process and subsequently the performance of a time-dependent model. Validation is the process of comparing modeled data to observed data during a period of time other than that used for calibration. During validation, no adjustments are made to model parameters. The goal of validation is to assess the capability of the model in hydrologic conditions other than those used during calibration.

As reported in Section 2.1, high concentrations of fecal coliform were recorded in all flow regimes, and a time period for calibration and validation was chosen based on the overall distribution of wet and dry seasons. The mean daily flow and precipitation for each season were calculated for the period October 1977 through September 1998. This resulted in 21 observations of flow and precipitation for each season. The mean and variance of these observations were calculated. Next, a representative period for modeling was chosen and compared to the historical data. The initial period was chosen based on the availability of mean 30-minute discharge data (10/1/94 – 9/30/98). Additional years, beginning with the fecal coliform assessment period (5/91 – 9/95), were added until the mean and variance of each season in the modeled time period was not significantly different from the historical data (Table 4.4). Therefore, the period was selected as representing the hydrologic regime of the study area, accounting for critical conditions associated with all potential sources within the watershed. The resulting time period for hydrologic calibration was October 1994 thru September 1998. For hydrologic validation the time period selected was October 1980 thru September 1981 and January 1991 thru September 1994.

Table 4.4 Comparison of modeled time period to historical records.

	Mean Flow (cfs)				Precipitation (in/day)			
	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer
	Historical Record (1978 - 1998)							
Mean	101	155	211	99	0.1223	0.1151	0.1365	0.1422
Variance	4,948	2,621	12,214	1,964	0.0023	0.0017	0.0018	0.0027
	Calibration & Validation Period (10/80 - 9/81, 1/91 - 9/98)							
Mean	77	172	194	101	0.1082	0.1285	0.1341	0.1375
Variance	3,320	3,749	7,442	2611	0.0023	0.0016	0.0015	0.0032
	P-Values							
Mean	0.178	0.228	0.322	0.453	0.241	0.203	0.440	0.416
Variance	0.289	0.762	0.224	0.719	0.536	0.495	0.396	0.648

4.6 Model Calibration and Validation Processes

Calibration and validation are performed in order to ensure that that the model accurately represents the hydrologic and water quality processes in the watershed. The model's hydrologic parameters were set based on available soils, land use, and topographic data. Qualities of fecal coliform sources were modeled as described in chapters 3 and 4. Through calibration these parameters were adjusted within appropriate ranges until the model performance was deemed acceptable.

4.6.1 Hydrologic Calibration and Validation

Parameters that were adjusted during the hydrologic calibration represent the amount of evapotranspiration from the root zone (LZETP), the recession rates for groundwater (AGWRC) and interflow (IRC), the length of overland flow (LSUR), the amount of soil moisture storage in the upper zone (UZSN) and lower zone (LZSN), the amount of interception storage (CEPSC), the infiltration capacity (INFILT), and the amount of soil water contributing to interflow (INTFW). Additionally, state variables in the PERLND water (PWAT) section of the User's Control Input (UCI) file were adjusted to reflect initial conditions.

The model was calibrated for hydrologic accuracy using 30-minute flow data from USGS Station #02056900 for the period October 1994 through September 1998 (Table 4.5). Results for the entire calibration period are plotted in Figure 4.4. Water year 1998 is represented in Figure 4.4 to portray the model performance on an annual scale.

Table 4.5 Hydrology calibration criteria and model performance for period 10/1/94 through 9/30/98.

Criterion	Simulated	Observed	% Error
Total annual runoff (in)	75.34	69.81	7.92
Total of highest 10% of flows (in)	25.54	26.67	-4.24
Total of lowest 50% of flows (in)	13.90	13.79	0.80
Summer flow volume (in)	13.76	13.65	0.81
Winter flow volume (in)	24.59	25.12	-2.11
Summer storm volume (in)	1.57	1.71	-8.19

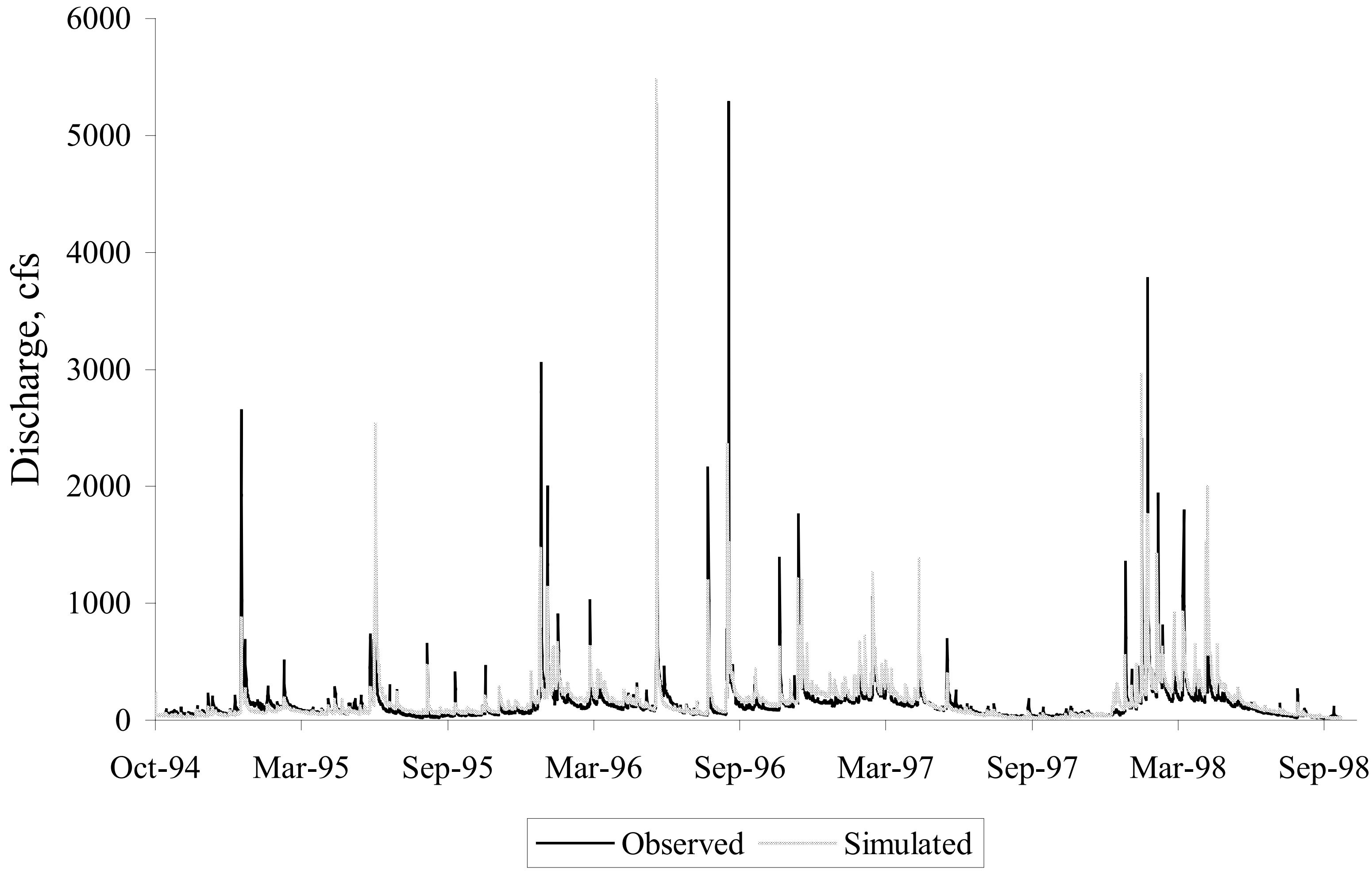

Figure 4.3 Calibration results for period 10/1/94 through 9/30/98.

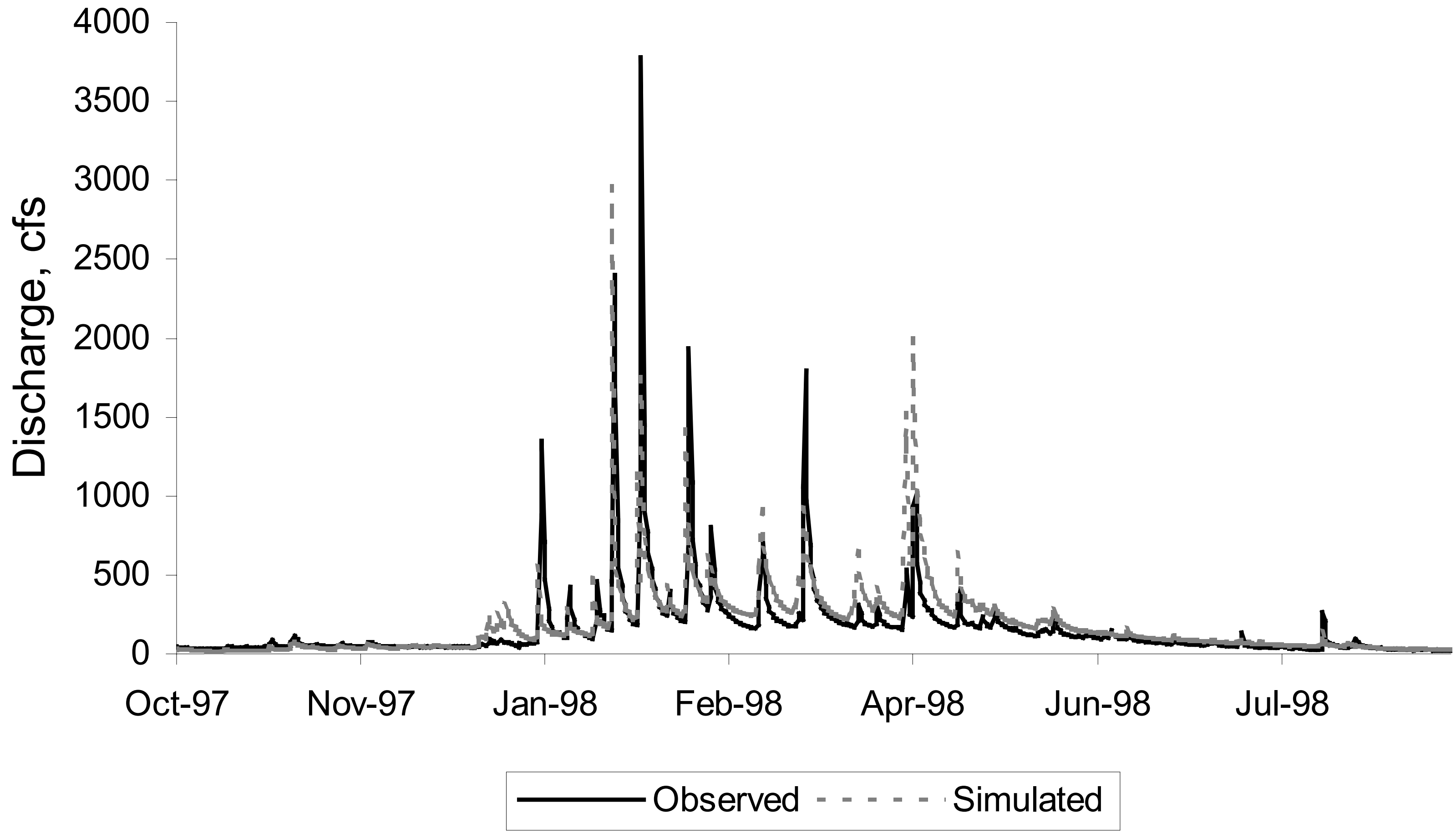

Figure 4.4 Calibration results for period 10/1/97 through 9/30/98.

The model was validated for the period January 1991 through September 1994 and October 1980 through September 1981 (Table 4.6). Only mean daily flows were available for this period. Validation results are included in Figure 4.5 through Figure 4.7.

Table 4.6 Hydrology validation criteria and model performance for validation period 1/1/91 through 9/30/94 and 10/1/80 through 9/30/81.

Criterion	Simulated	Observed	% Error
Total annual runoff (in)	66.19	72.59	-8.82
Total of highest 10% of flows (in)	22.14	26.78	-17.33
Total of lowest 50% of flows (in)	13.75	15.31	-10.19
Summer flow volume (in)	12.80	14.17	-9.67
Winter flow volume (in)	17.90	19.01	-5.84
Summer storm volume (in)	0.63	0.65	-3.08

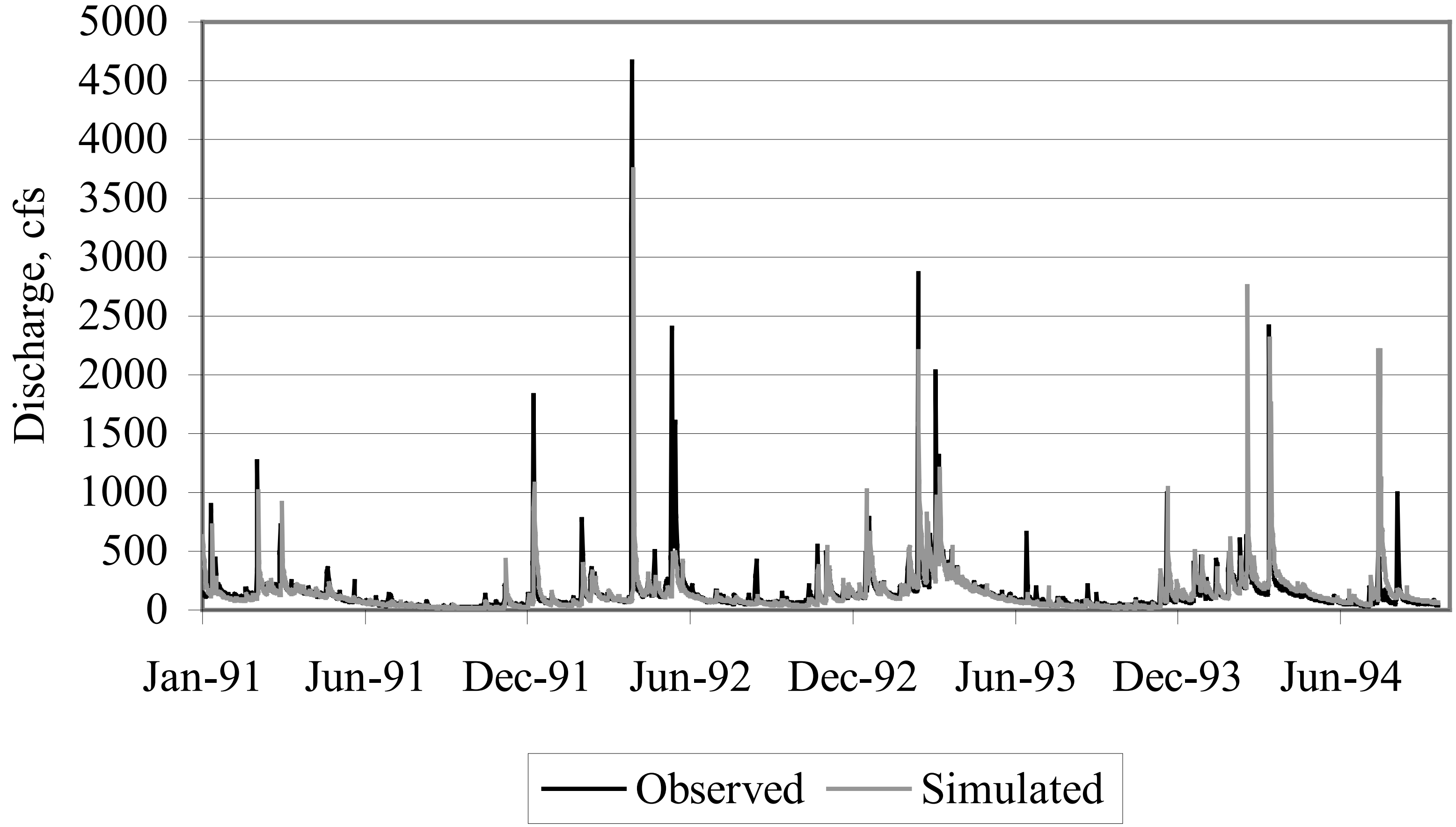

Figure 4.5 Validation results for period 1/1/91 through 9/30/94.

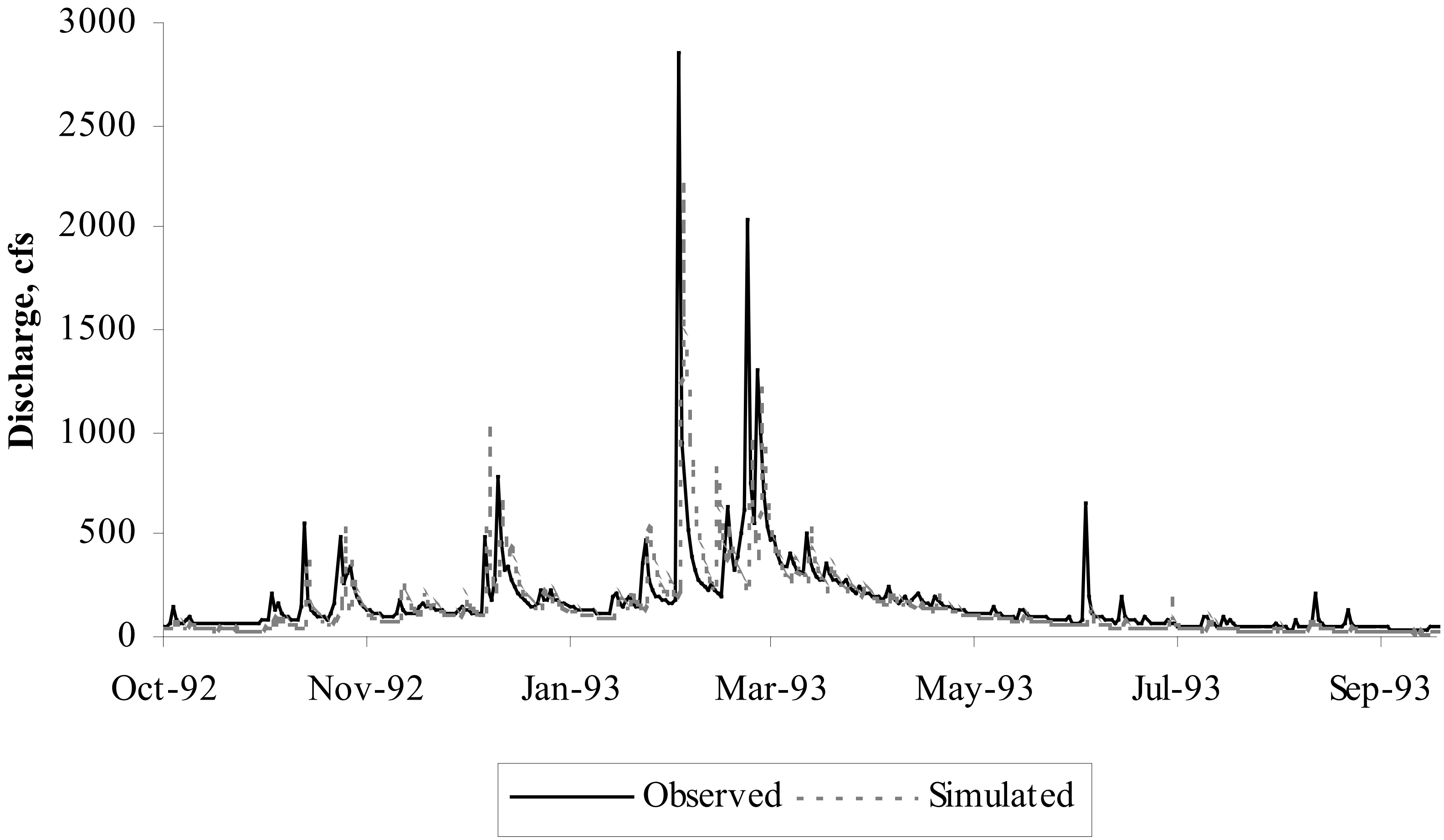

Figure 4.6 Validation results for period 10/1/92 through 9/30/93.

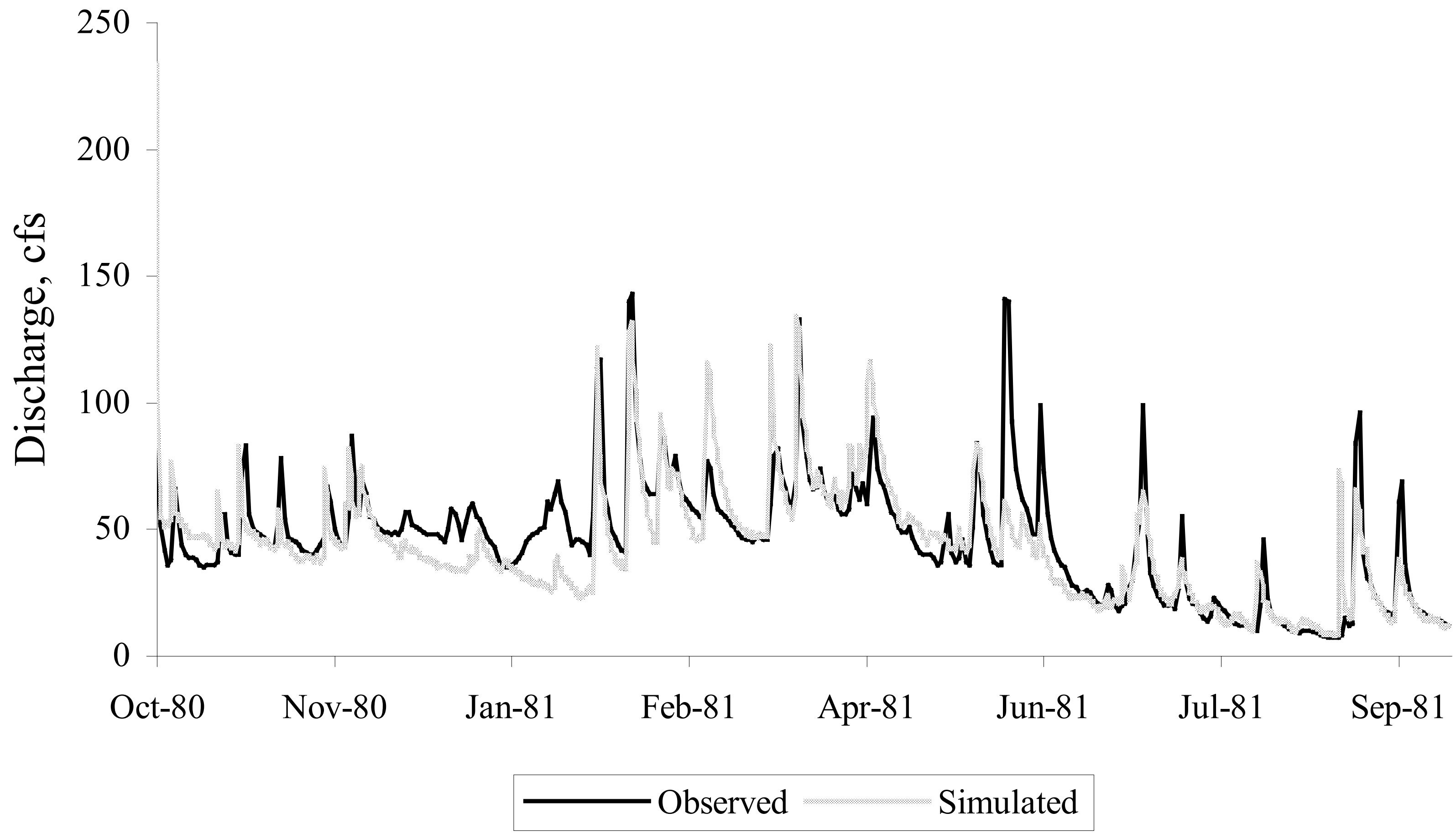

Figure 4.7 **Validation results for period 10/1/80 through 9/30/81.**

In addition, instantaneous flow measurements taken by VADEQ during water quality sampling were used to calculate the average ratio of flow at the water quality sampling sites to flow at USGS Station #02056900. These ratios were compared to ratios based on model output to determine if HSPF was adequately representing flow at the subwatershed scale (Table 4.7).

Table 4.7 Subwatershed calibration results in the Upper Blackwater watershed for the period 10/1/94 through 9/30/98.

WQ Monitoring Station	Modeled Data % of USGS #02056900	Monitored Data % of USGS #02056900
4ABWR061.20	62 %	71 %
4ABWR054.81	65 %	n/a

4.6.2 Water Quality Calibration and Validation

Water quality calibration is complicated by a number of factors, some of which are described here. First, water quality concentrations (e.g. fecal coliform concentrations) are highly dependent on flow conditions. Any variability associated with the modeling of stream flow compounds the variability in modeling water quality parameters such as fecal coliform concentration. Second, the concentration of fecal coliform is particularly variable. Variability in location and timing of fecal deposition, variability in the density of fecal coliform bacteria in feces (among species and for an individual animal), environmental impacts on regrowth and die-off, and variability in delivery to the stream all lead to difficulty in measuring and modeling fecal coliform concentrations. Additionally, the limited amount of measured data for use in calibration and the practice of censoring both high (over 8,000 cfu/100 ml) and low (under 100 cfu/100 ml) concentrations impede the calibration process.

The water quality calibration was conducted from 1/1/93 through 12/31/95. Only four parameters were available for adjustment in the model; in-stream first-order decay rate (FSTDEC), maximum accumulation on land (SQOLIM), rate of surface runoff that will remove 90% of stored fecal coliform per hour (WSQOP), and concentration of fecal coliform in interflow (IOQC). All these parameters were initially set at expected levels for the watershed conditions and adjusted within reasonable limits until an acceptable match between measured and modeled fecal coliform concentrations was established. Figures 4.9 through 4.10 show the results of calibration. Short-period fluctuations in the modeled data denote the effective modeling of the variability within daily concentrations that was achieved through distributing direct depositions from wildlife, livestock, and uncontrolled discharges across each day (Section 4.3).

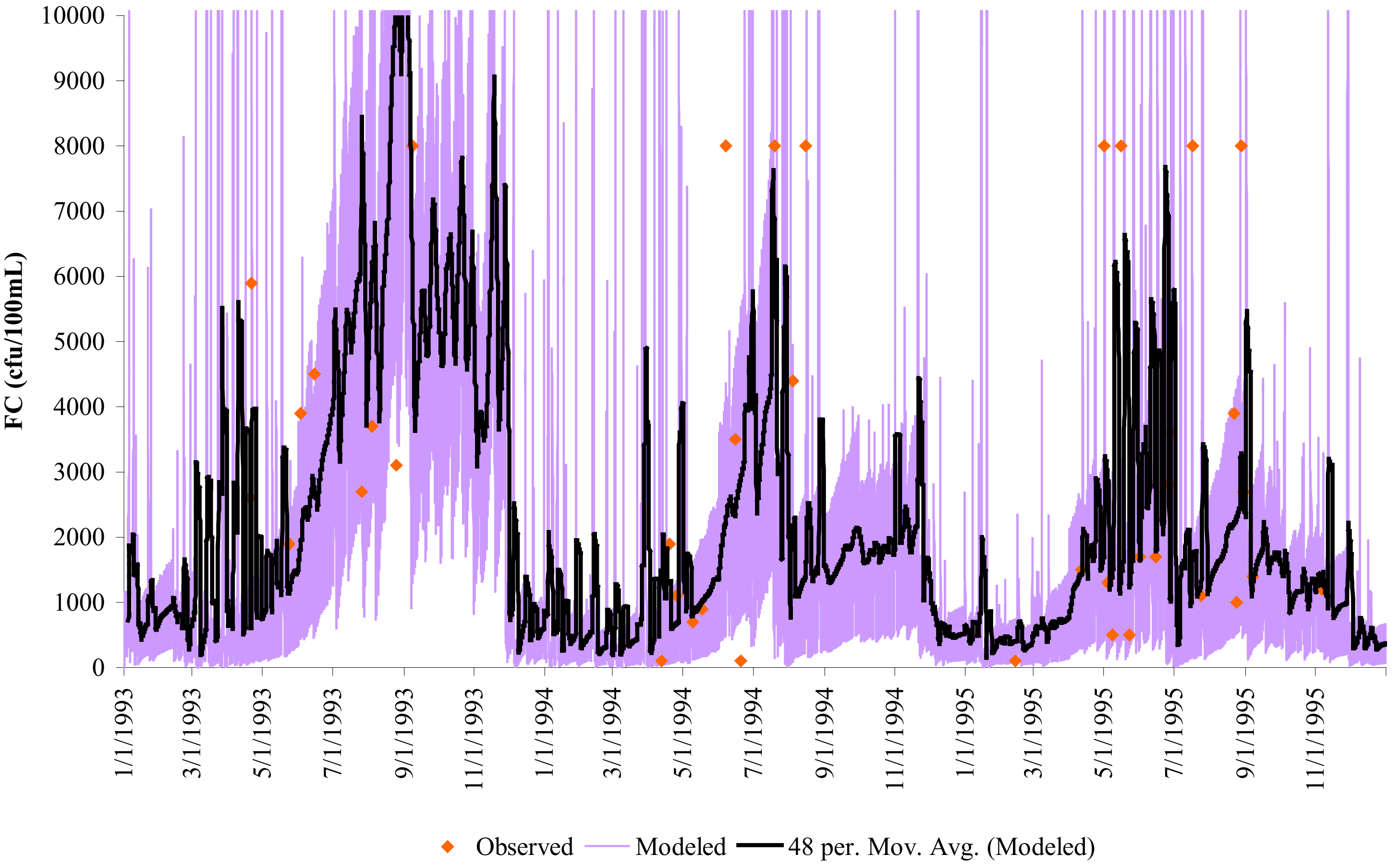

Figure 4.8 Quality calibration for subwatershed 8 of Upper Blackwater impairment.

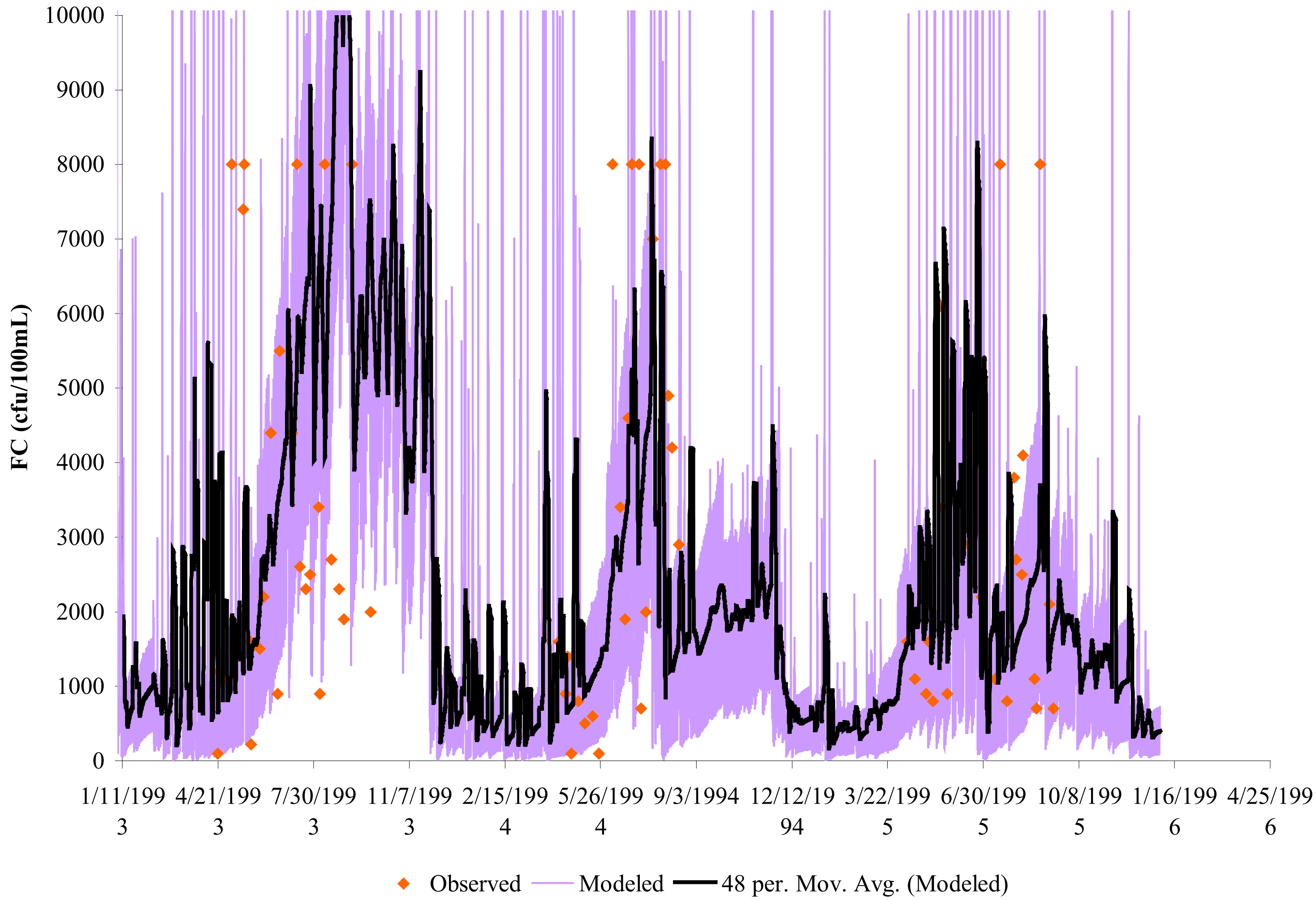

Figure 4.9 Quality calibration for subwatershed 10 of Upper Blackwater impairment.

Careful visual inspection of graphical comparisons between continuous simulation results and limited observed points was the primary tool used to guide the calibration process. Additionally, to provide a better quantitative measure of the agreement between modeled and measured data while taking the inherent variability of fecal coliform concentrations into account, each observed value was compared with modeled concentrations in a 2-day window surrounding the observed data point. First, the minimum and maximum modeled values in each modeled window was determined. Figures 4.11 and 4.12 show the relationship between these extreme values and observed data. In addition, standard error in each observation window was calculated as follows:

$$Standard\ Error = \frac{\sqrt{\dfrac{\sum_{i=1}^{n}\left(observed - modeled_i\right)^2}{(n-1)}}}{\sqrt{n}}$$

where

$$\begin{aligned} observed &= \text{an observed value of fecal coliform,} \\ modeled_i &= \text{a modeled value in the 2-day window surrounding the observation, and} \\ n &= \text{the number of modeled observations in the 2-day window.} \end{aligned}$$

This is a non-traditional use of standard error, applied here to offer a quantitative measure of model accuracy. In this context, standard error measures the variability of the sample mean of the modeled values about an instantaneous observed value. The use of limited instantaneous observed values to evaluate continuous data introduces error and therefore increases standard error. The mean of all standard errors for each station analyzed was calculated. Additionally, the maximum concentration values observed in the simulated data were compared with maximum values obtained from uncensored data (Section 2) and found to be at reasonable levels (Table 4.8).

Table 4.8 Results of analyses on calibration runs.

WQ Monitoring Station	Mean Standard Error (cfu/100 ml)	Maximum Simulated Value (cfu/100 ml)
4ABWR061.20	193	115,760
4ABWR054.81	193	84,365

The water quality validation was conducted for the time period from 1/1/91 to 12/31/92. The relationship between observed values and modeled values can be seen in Figures 4.13 through 4.16. The results of standard error and maximum value analyses are reported in Table 4.9. Standard errors calculated from validation runs were comparable to standard errors calculated from calibration runs. Maximum simulated values were comparable to observed maximum values in the area (Section 2).

Table 4.9 Results of analyses on validation runs.

WQ Monitoring Station	Mean Standard Error (cfu/100 ml)	Maximum Simulated Value (cfu/100 ml)
4ABWR061.20	243	225,840
4ABWR054.81	191	151,880

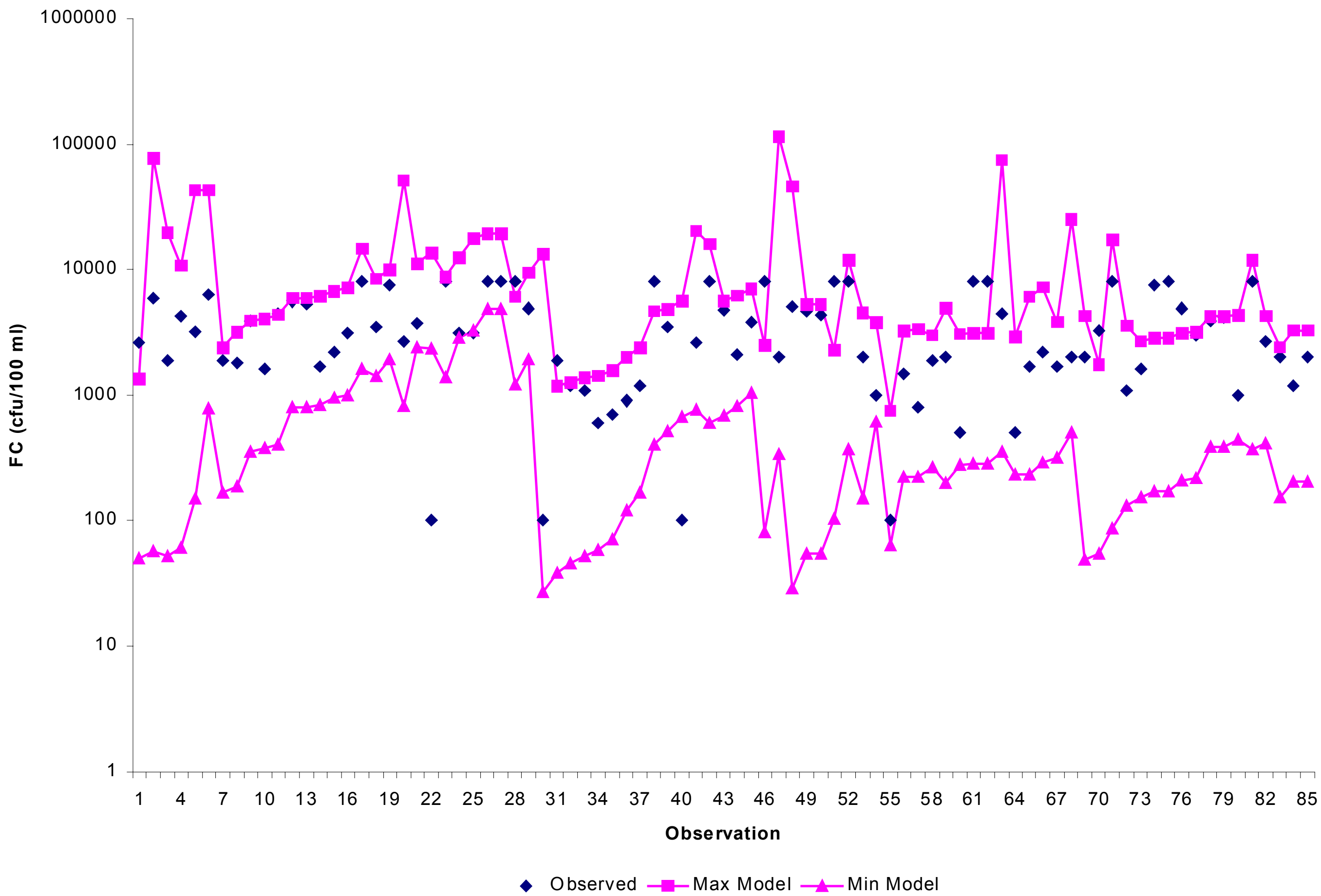

Figure 4.10 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Calibration period for watershed 8 in the Upper Blackwater impairment.

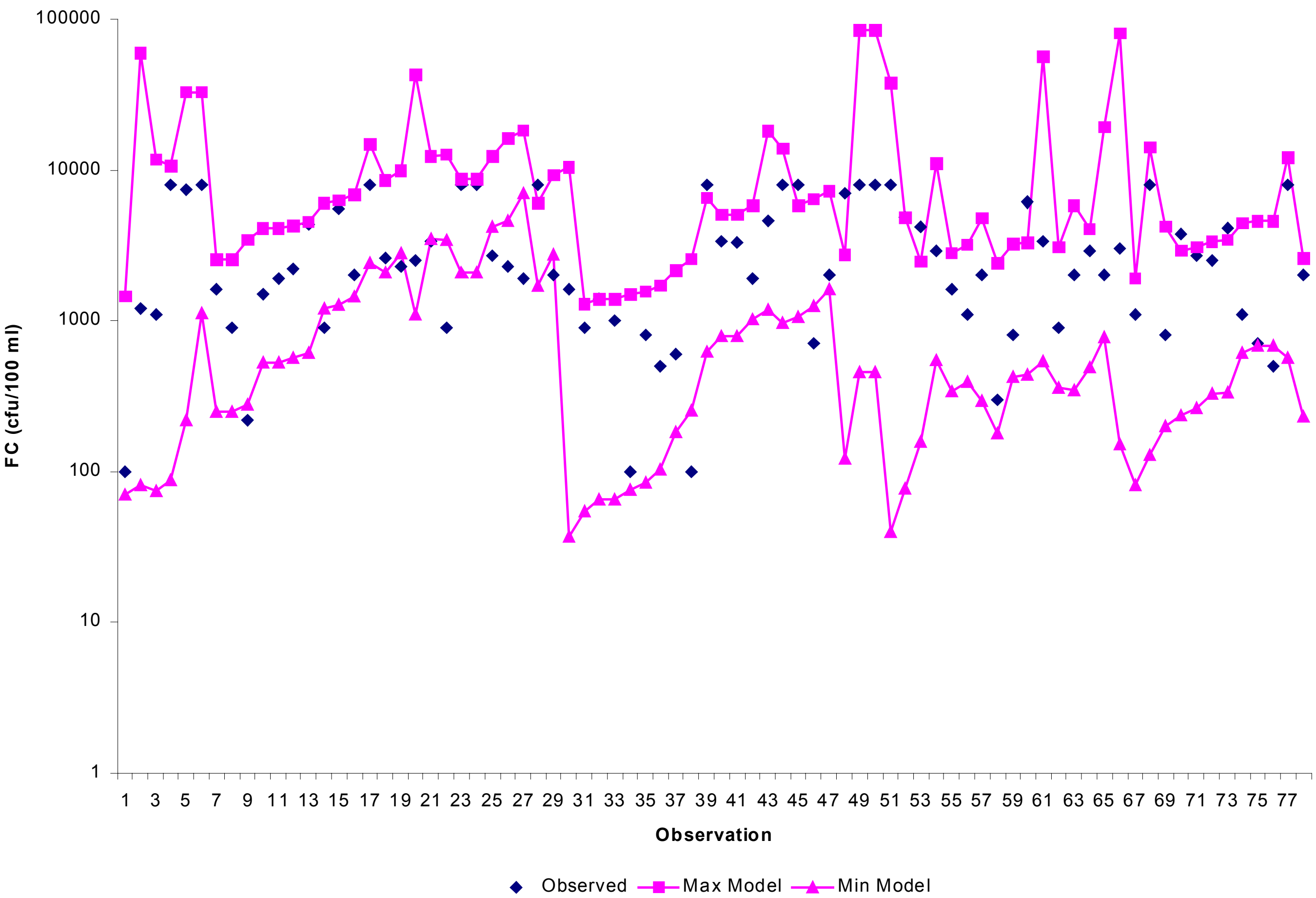

Figure 4.11 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Calibration period for watershed 10 in the Upper Blackwater impairment.

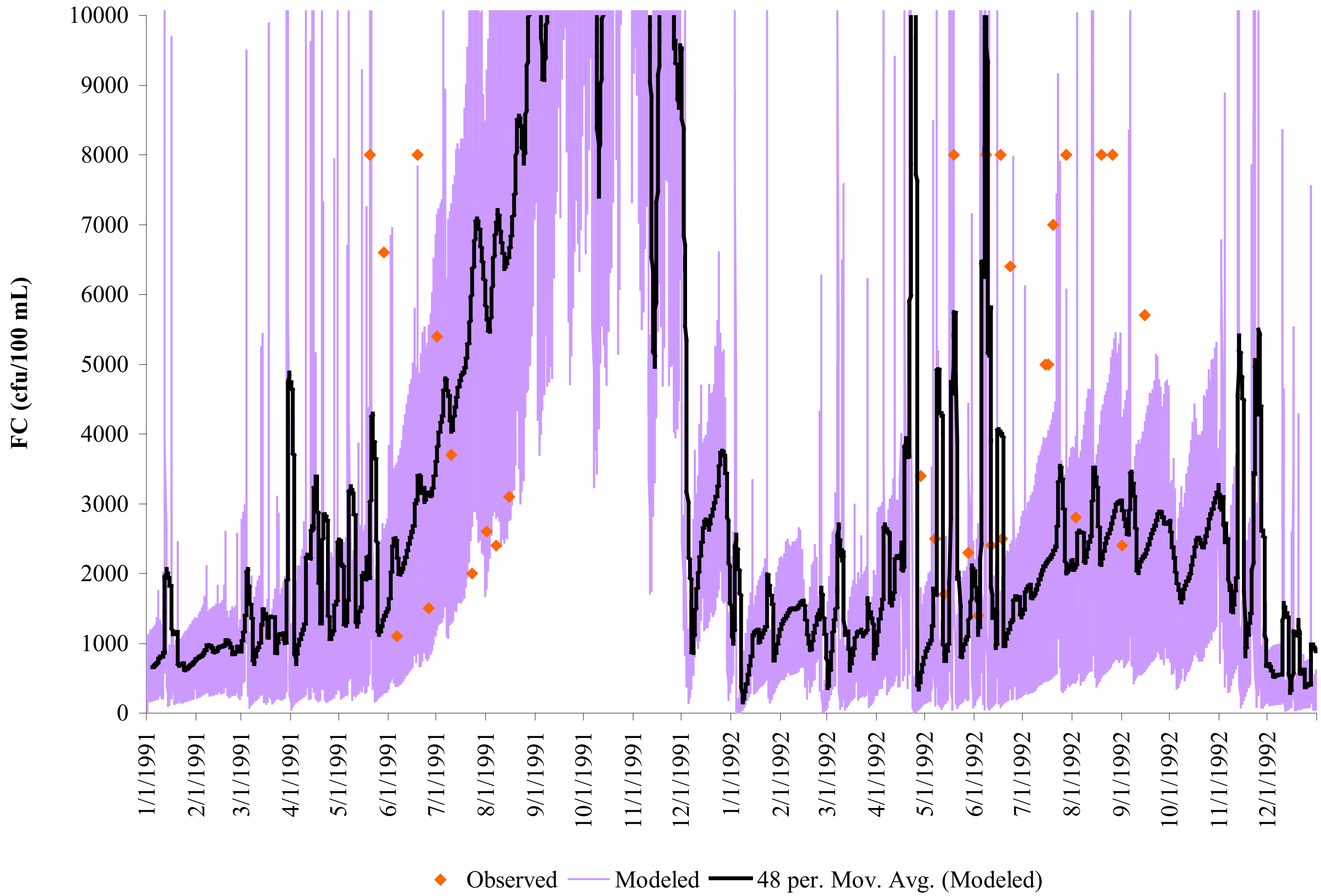

Figure 4.12 Quality validation for subwatershed 8 of Upper Blackwater impairment.

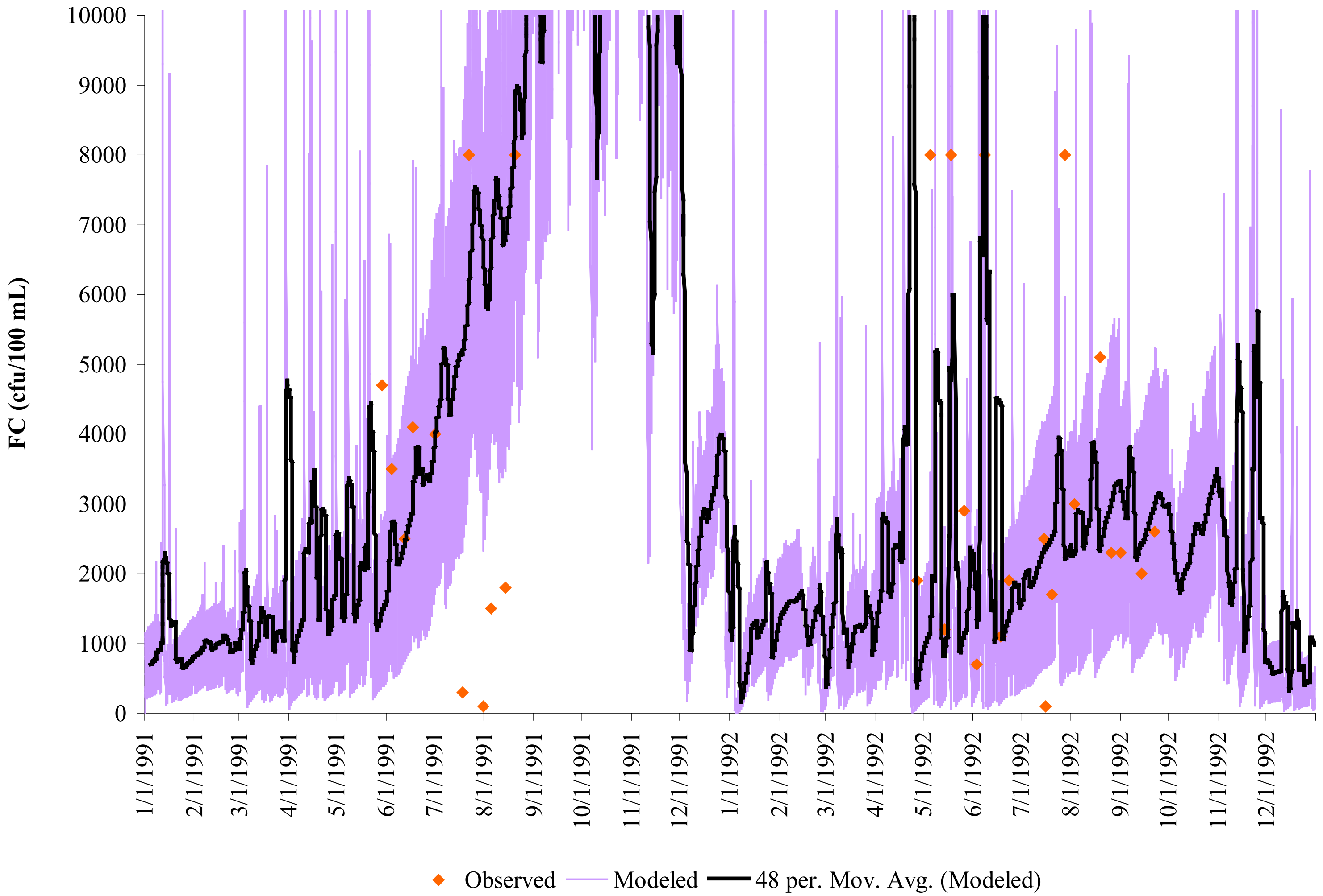

Figure 4.13 Quality validation for subwatershed 10 of Upper Blackwater impairment.

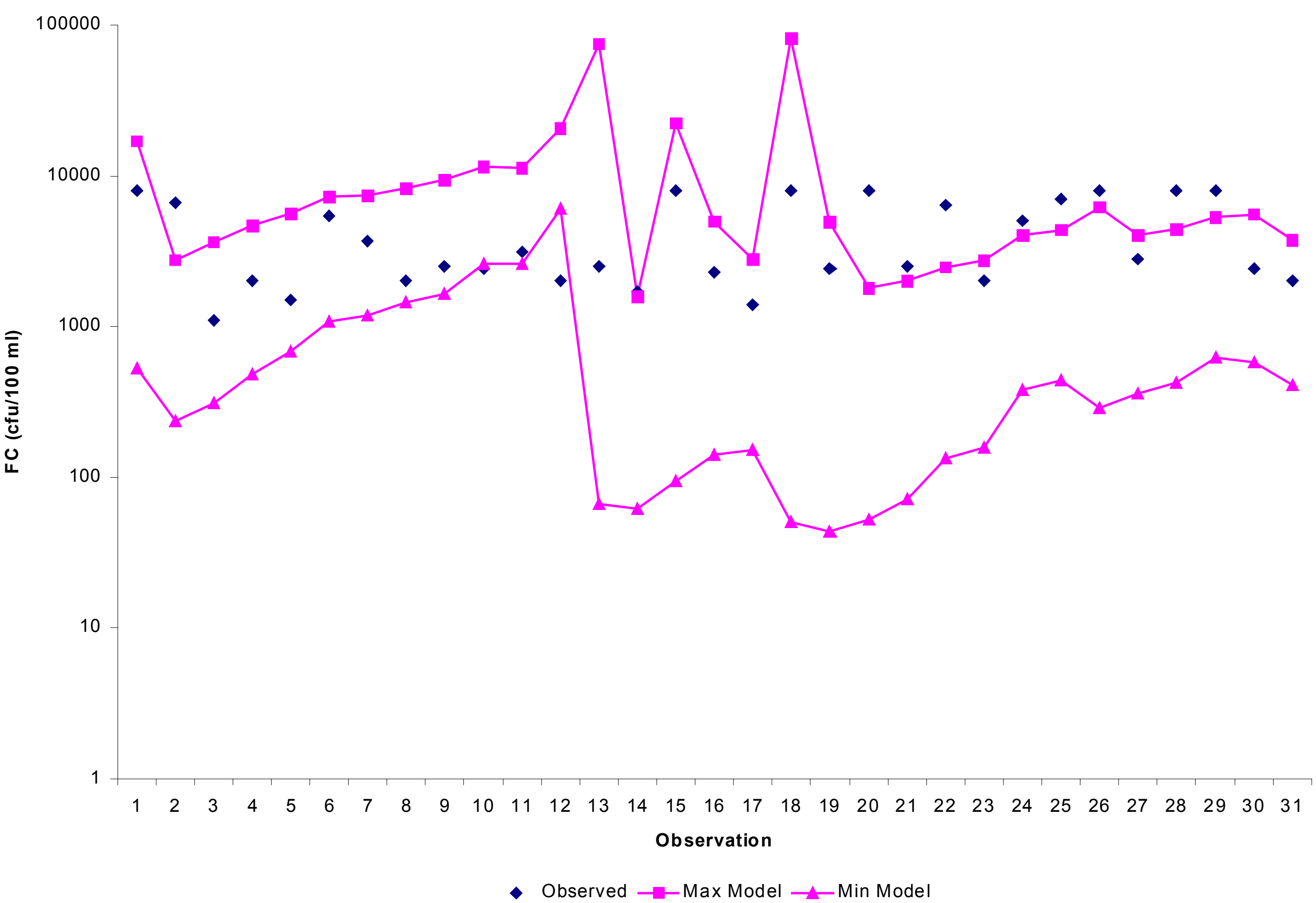

Figure 4.14 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 8 of Upper Blackwater impairment.

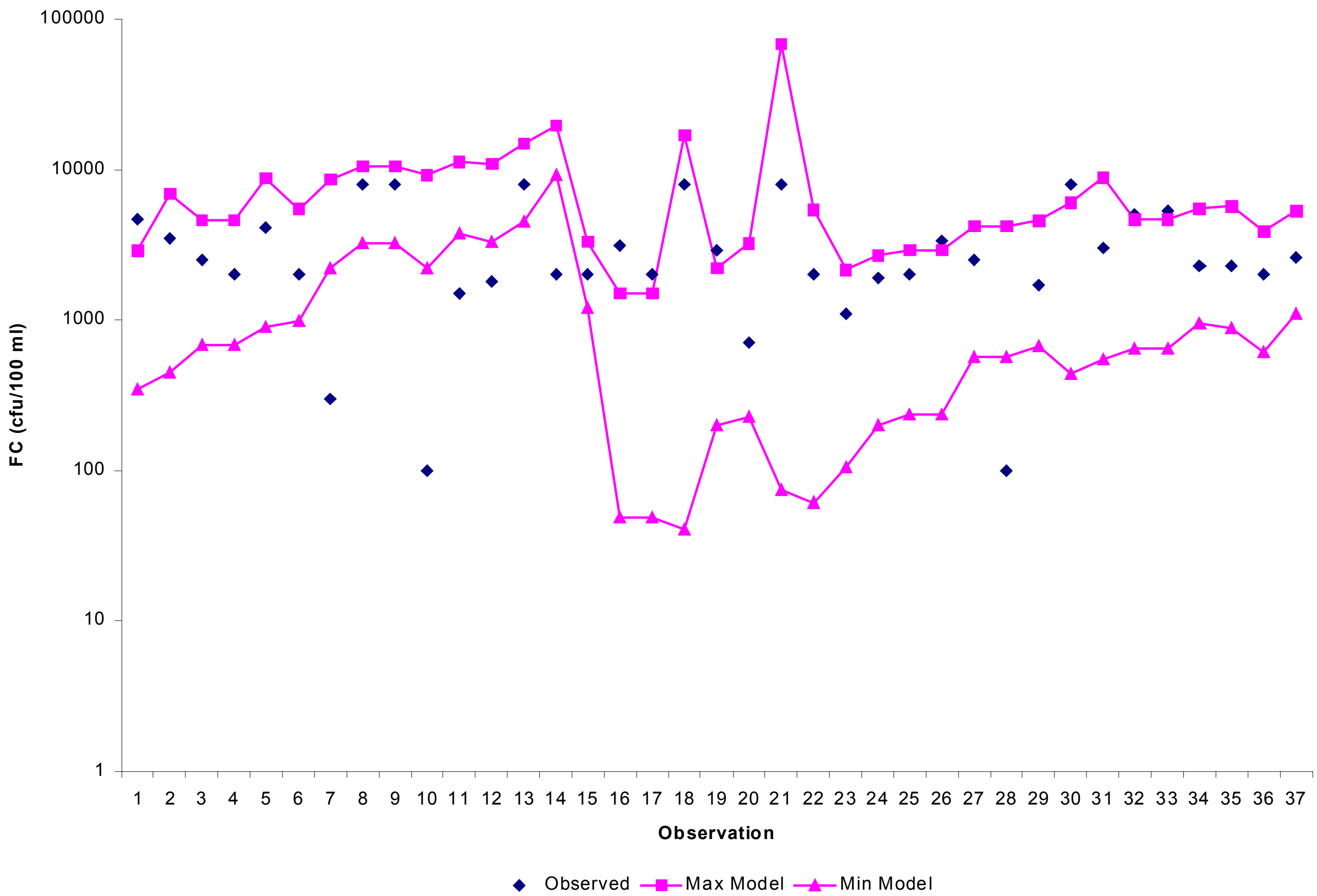

Figure 4.15 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 10 of Upper Blackwater impairment.

4.7 Existing Loadings

All appropriate inputs were updated to 1999 conditions, as described in Section 4. All remaining model runs were conducted using precipitation data for the representative time period used for water quality calibration and validation (1/1/91 through 12/31/95). Figure 4.17 shows the 30-day geometric mean of fecal coliform concentrations in relation to the 200 cfu/100 ml standard.

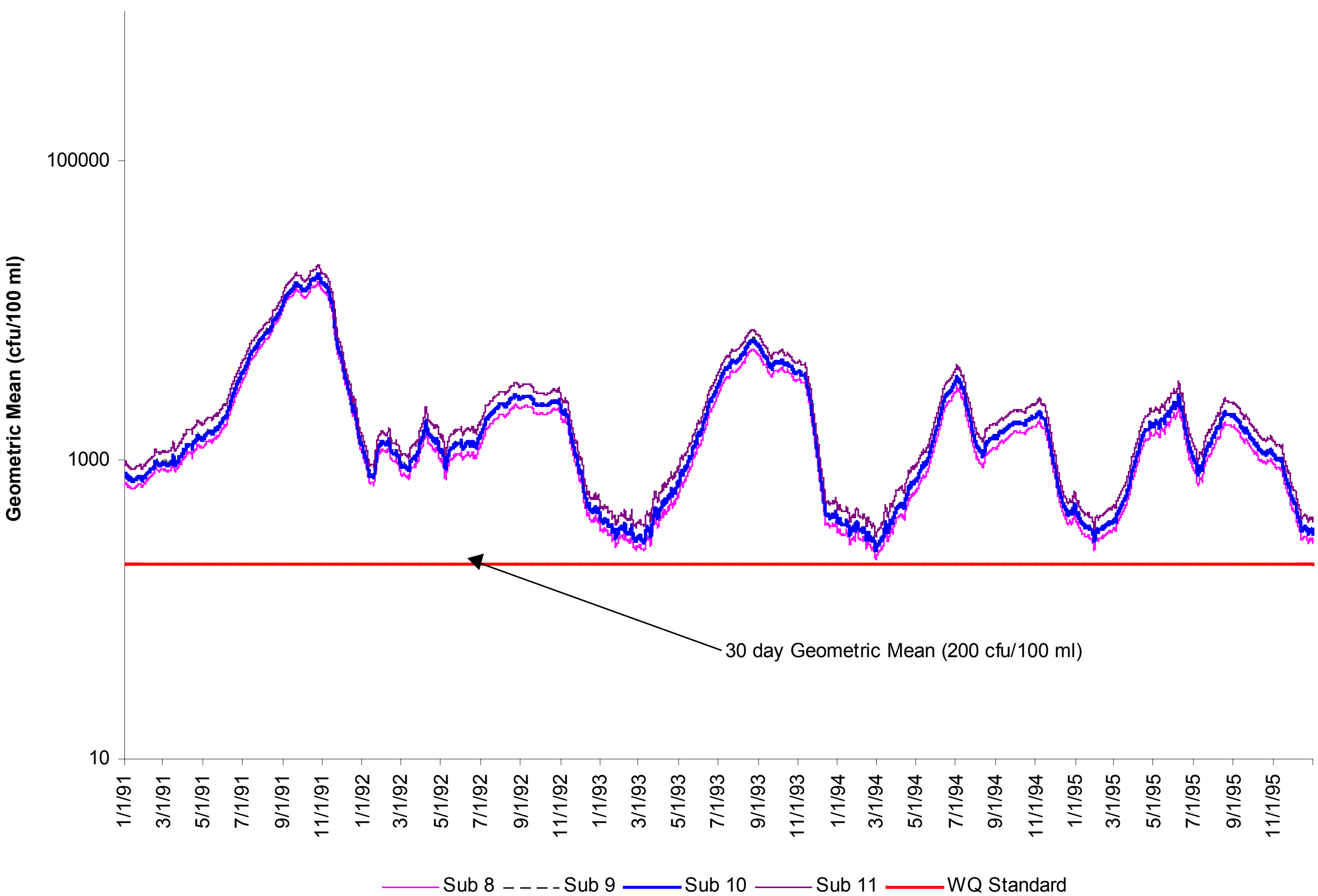

Figure 4.16 Existing conditions in subwatersheds 8-11 of Upper Blackwater impairment.

5. ALLOCATION

Total Maximum Daily Loads (TMDLs) consist of waste load allocations (WLAs, point sources) and load allocations (LAs, nonpoint sources) including natural background levels. Additionally, the TMDL must include a margin of safety (MOS) that either implicitly or explicitly accounts for the uncertainties in the process (e.g. accuracy of wildlife populations). The definition is typically denoted by the expression:

TMDL = WLAs + LAs + MOS

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving waterbody and still achieve water quality standards. For fecal coliform bacteria, TMDL is expressed in terms of cfu (or resulting concentration). A sensitivity analysis was performed to determine the impact of uncertainties in input parameters.

5.1 Sensitivity Analysis

Sensitivity analyses were conducted to assess the impact of unknown variability in source allocation (e.g., seasonal and spatial variability of waste production rates for wildlife, livestock and septic system failures, uncontrolled discharges), background loads, and point source loads. Additional analyses were made to define the sensitivity of the system to growth or technology changes that impact waste production rates.

An initial base run was performed using precipitation data from 1995 and model parameters established for 1999 conditions. Three sources of fecal coliform were considered in the sensitivity analyses; land-based loadings, uncontrolled discharges, and direct deposition to the stream by livestock. Each of these sources was adjusted by four percentages (±10%, ±100%). Corresponding reductions were made in all upstream impairments as well. The resulting percent change in total annual fecal coliform bacteria load leaving the impairment area was recorded, and is presented in Figure 5.1.

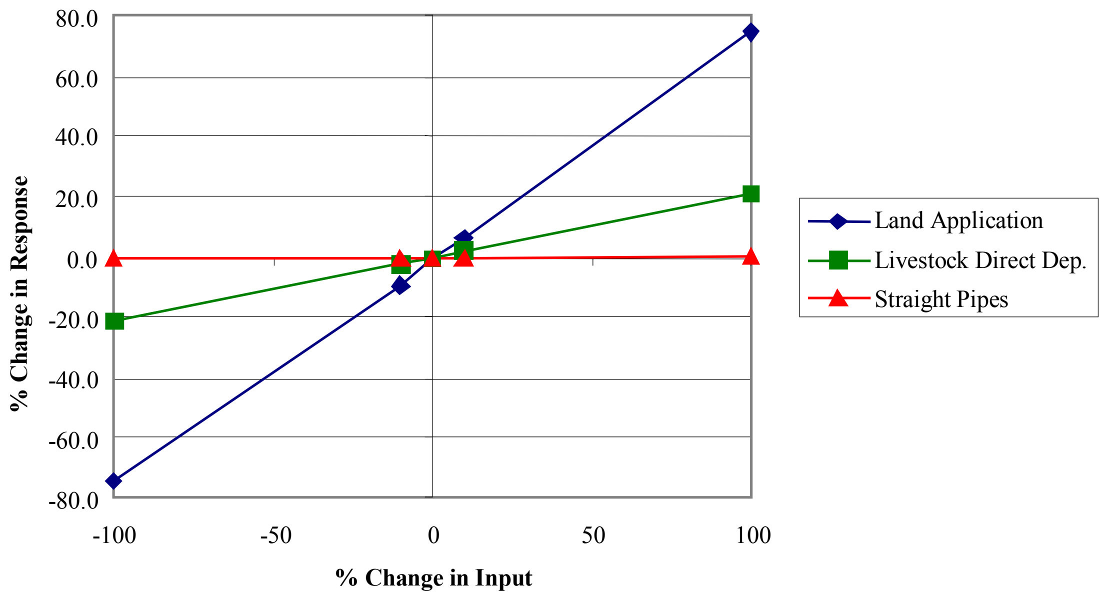

Figure 5.1 Results of total loading sensitivity analysis for the Upper Blackwater watershed.

Since the water quality standard for fecal coliform bacteria is based on concentrations rather than loadings, it was considered necessary to analyze the effect of source changes on the 30-day geometric-mean fecal coliform concentration. A running, 30-day, geometric mean was calculated at each 15-minute time-step, and the maximum value for each month was recorded. Deviations from the base run are plotted by month in Figures 5.2 through 5.4.

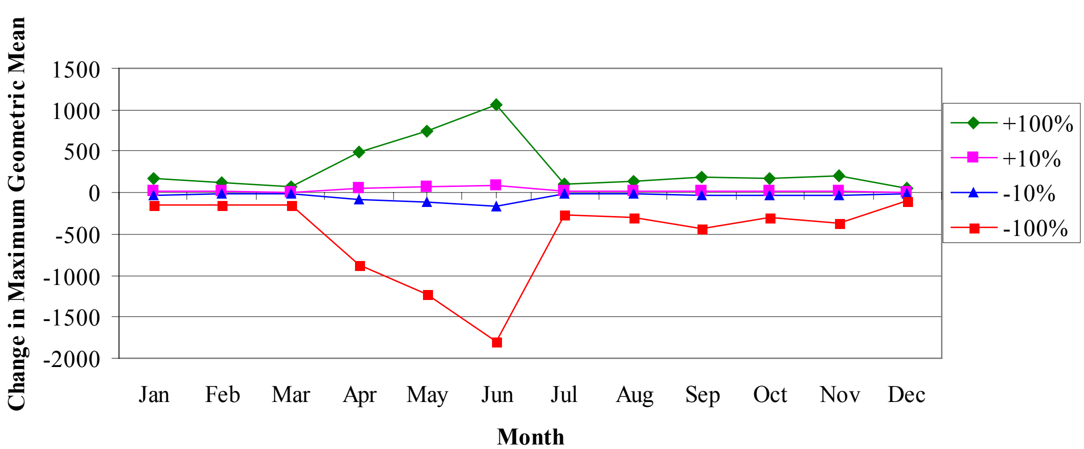

Figure 5.2 Results of sensitivity analysis on 30-day, geometric-mean concentrations in the Upper Blackwater watershed, as affected by changes in land-based loadings.

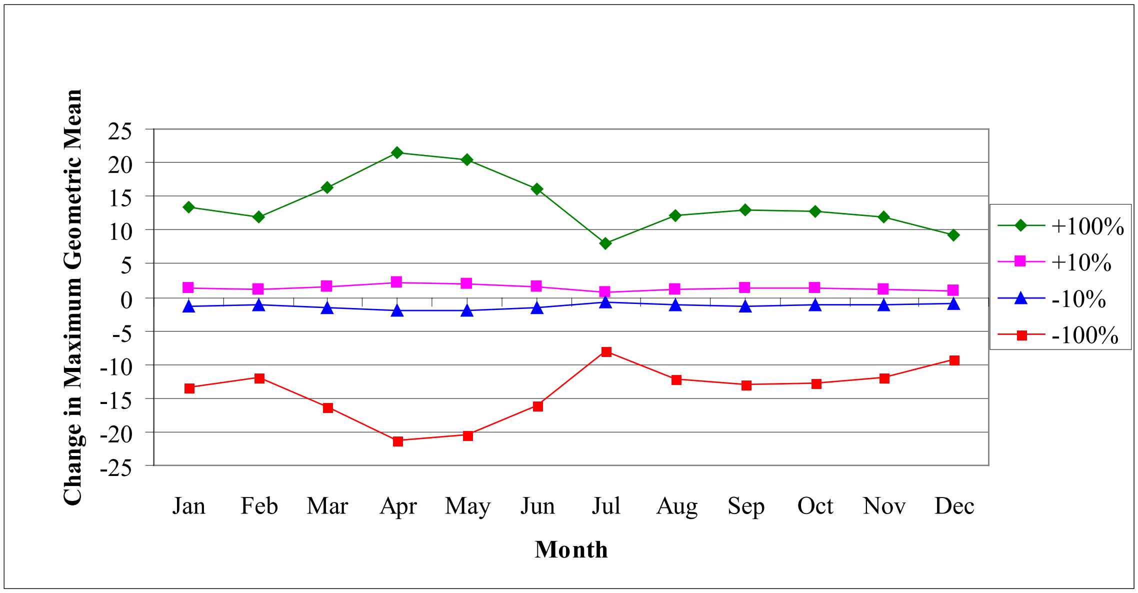

Figure 5.3 Results of sensitivity analysis on 30-day, geometric-mean concentrations in the Upper Blackwater watershed, as affected by changes in loadings from uncontrolled discharges.

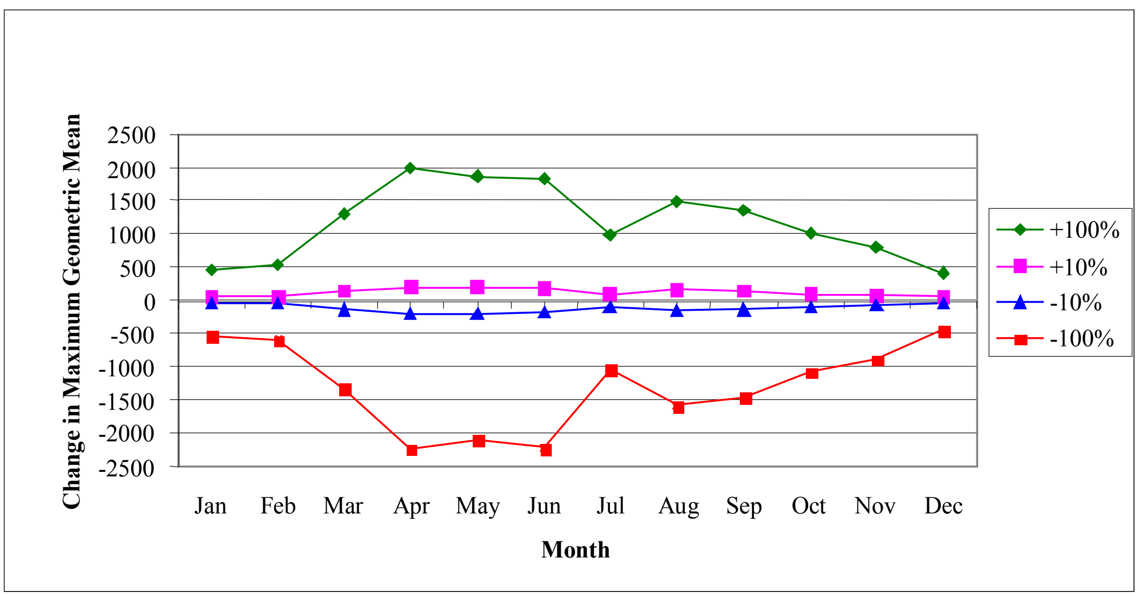

Figure 5.4 Results of sensitivity analysis on 30-day, geometric-mean concentrations in the Upper Blackwater watershed, as affected by changes in loadings from direct deposition by livestock.

5.2 Incorporation of a Margin of Safety

A margin of safety (MOS) was incorporated into the TMDL in an effort to account for scientific errors inherent to the TMDL development process, measurement uncertainty in model parameters, and to account for trends which might prevent the water quality goal, as targeted by the TMDL, from being achieved. Scientific errors arise from our inability to fully describe mathematically the processes and mechanisms through which pollutants are delivered to the stream. Model calibration is an attempt to address these errors through adjusting model parameters until a suitable fit to observed data is achieved. Measurement uncertainty also introduces errors in the model calibration, because model parameters that are adjusted to non-representative conditions result in model simulations being biased either low or high. For example, observed data used for model calibration were collected for the purpose of detecting violations of the state's water quality standards. As a result, sample analyses are arbitrarily censored at a level above the state standard. This introduces modeling uncertainty during events that produce high pollutant concentrations. To insure a pollutant reduction, long-term trends in pollutant sources must be considered in load allocations. For instance, if livestock populations within the targeted watershed are increasing, then a larger MOS might be appropriate to account for the expected increase in loads.

The MOS is a subjective value, representing a balance between complete certainty of reaching the in-stream standard and not meeting the standard. The MOS was entered explicitly as 5% of the maximum 30-day geometric mean standard (200 cfu/100 ml). The result was that allocation scenarios were developed with the goal of maintaining the modeled 30-day geometric mean below 190 cfu/100 ml.

5.3 Scenario Development

Allocation scenarios were modeled using HSPF. Existing conditions (Table 5.1) were adjusted until the water quality standard was attained. The standard included the geometric mean of 200 cfu/100ml along with the MOS described in Section 5.2. The development of the allocation scenario was an iterative process that required numerous runs with each followed by an assessment of source reduction against the water quality target. Additional reductions were made until the target was achieved.

5.3.1 Wasteload Allocations

There are no permitted point sources located within the Upper Blackwater impairment. Therefore, there were no wasteload allocations necessary for this impairment.

5.3.2 Load Allocations

Load allocations to nonpoint sources are divided into land-based loadings from land uses and direct applied loads in the stream (e.g. livestock, septic systems within 50 feet of a stream, and wildlife). Source reductions include those that are affected by both high and low flow conditions. Within this framework, however, initial criteria that influenced developing load allocations included how sources were linked for representing existing conditions, and results from bacteria source tracking in the area. Direct deposition nonpoint sources were modeled with consistent loadings to the stream regardless of flow regime and had a significant impact on low flow concentrations. Bacteria source tracking during three fall 1999 sampling periods confirmed the presence of human, livestock and wildlife contamination.

With the impact of in-stream deposition very large, and the presence of human, livestock, and wildlife fecal material, an initial scenario was 100% reduction of uncontrolled residential discharges and 90% reduction in livestock stream access. All land-based allocations remained at existing conditions, that is zero reduction.

This resulted in significant exceedances of the geometric mean standard (Table 5.1, Scenario A). The exceedances all occurred in historically low flow periods (Table 2.4). With the exception of this period, all geometric means are less then 50% of the target. A review of discharge data reveals that the discharge for the period is nearly equal to the twenty year low. These periods are nearly totally dominated by in-stream deposition limiting the scenarios to achieve the target to a reduction of livestock to 100% (i.e. total exclusion from streams), reduction of wildlife, and/or reduction of lateral flow from septic systems within 50 feet of streams. However, 100% reduction of livestock direct deposition did not meet the standard (Table 5.1, Scenario B). Additional scenarios were explored incorporating a reduction in land-based loads (e.g. Table 5.1, Scenario C) resulting in minimal reduction in the percent of exceedances.

Additional scenarios were modeled to achieve the target through the reduction of direct deposition, the dominant impacting source for these low flow conditions. A scenario including lateral flow from septic systems within 50 feet of streams had only a minor impact on the geometric mean for the low flow period. A scenario removing all sources except wildlife resulted in a continued exceedances in Fall 1991, a period of particularly low flows (Table 5.1, Scenario D).

Several model runs were made investigating scenarios that involved the reduction of wildlife required to meet the standard for the low flow condition. The final scenario involved a 60% reduction (Figure 5.5, Table 5.1). The load allocation becomes no reduction of land applied fecal material, no reduction of septic systems within fifty feet of streams since the impact was negligible, 100% reduction of livestock in-stream deposition, 100% reduction of uncontrolled residential discharges and 75% reduction of wildlife in-stream deposition (Tables 5.2 and 5.3). Although there is no reduction of land applied fecal material, implicit in allocation is a need to maintain loadings at or below the current levels.

Table 5.1 Percentage of 30-day geometric mean values exceeding 190 cfu/100 ml fecal coliform in the Upper Blackwater River impairment.

Scenario Description		Exceedances
Existing conditions as of 1999		100.0%
Scenario A:	-100% human straight pipes, - 90% livestock direct deposition	68.7%
Scenario B:	-100% livestock direct deposition, -100% human straight pipes	5.4%
Scenario C:	-100% livestock direct deposition, -100% human straight pipes, -50% of land-based loads from livestock, pets, and failed septic	3.2%
Scenario D:	Wildlife loads only included	2.0%
Final Allocation Scenario		0.0%

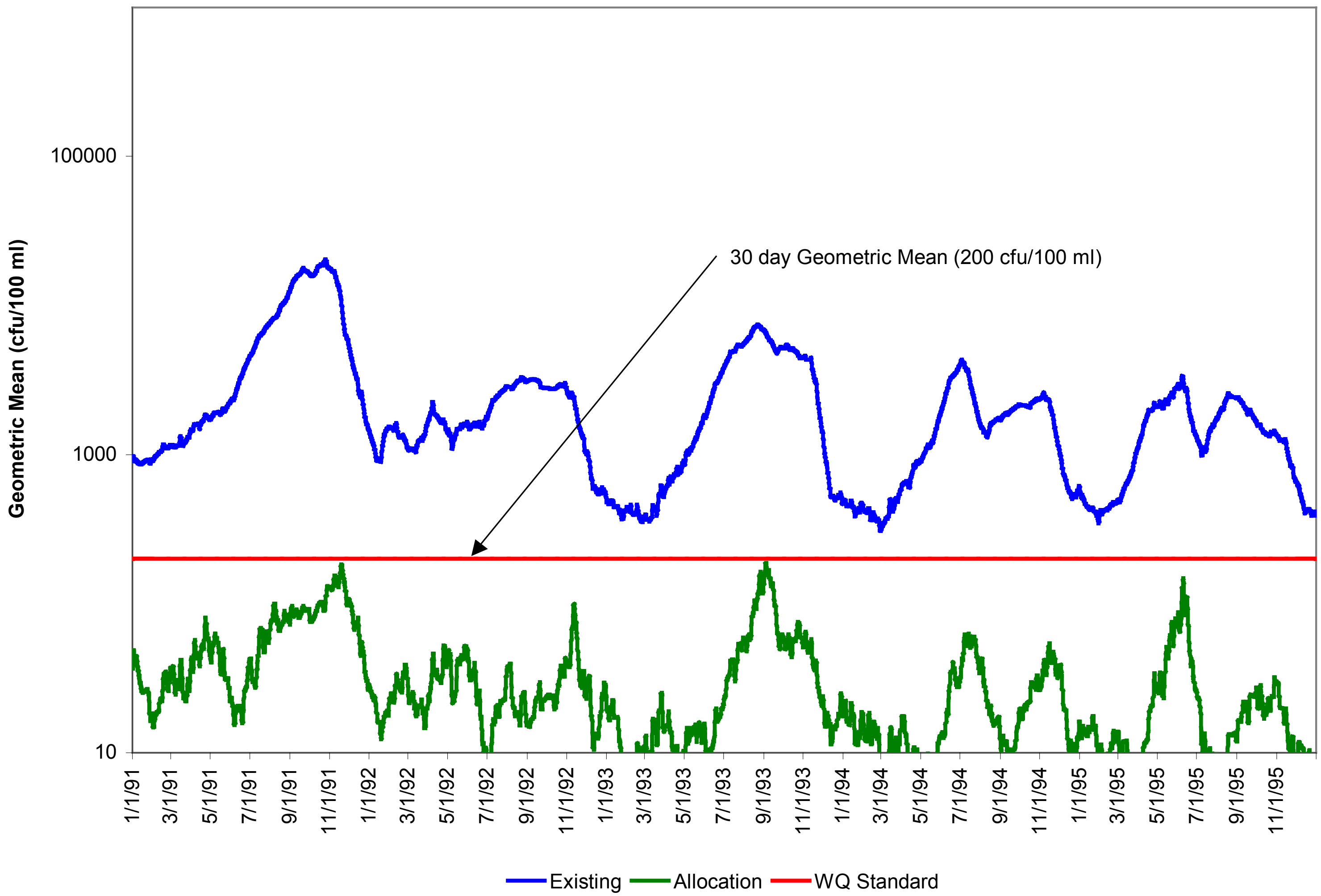

Figure 5.5 Allocation and existing scenarios for Upper Blackwater impairment.

Table 5.2 Land-based nonpoint source load reductions in the Upper Blackwater impairment for final allocation.

Land use	Total annual loading for existing run (cfu/yr)	Total annual loading for allocation run (cfu/yr)	Percent Reduction
Good Pasture	1.43E+16	1.43E+16	0
Poor Pasture	4.50E+14	4.50E+14	0
Cropland	7.97E+16	7.97E+16	0
Forest	2.16E+14	2.16E+14	0
Urban	2.08E+14	2.08E+14	0
Farmstead	1.59E+13	1.59E+13	0
Livestock Access	1.67E+14	5.49E+14	-229
Loafing Lot	4.02E+14	4.02E+14	0

Table 5.3 Load reductions to direct nonpoint sources in the Upper Blackwater impairment for final allocation.

Subw'shed	Wildlife (cfu/year)			Straight Pipes (cfu/year)		
	Existing load	Allocated load	% Red.	Existing load	Allocated load	% Red.
8	1.16E+12	2.91E+11	75	5.75E+11	0.00E+00	100
9	3.74E+11	9.53E+10	75	5.59E+11	0.00E+00	100
10	6.50E+11	1.62E+11	75	7.92E+11	0.00E+00	100
11	1.05E+12	2.63E+11	75	5.11E+11	0.00E+00	100
TOTAL	3.24E+12	1.14E+12	75	2.44E+12	0.00E+00	100

Subw'shed	Lateral Flow (cfu/year)			Livestock (cfu/year)		
	Existing load	Allocated load	% Red.	Existing load	Allocated load	% Red.
8	3.44E+07	3.44E+07	0	1.03E+14	0.00E+00	100
9	3.50E+07	3.50E+07	0	1.01E+14	0.00E+00	100
10	1.85E+07	1.85E+07	0	2.65E+13	0.00E+00	100
11	4.93E+07	4.93E+07	0	1.52E+14	0.00E+00	100
TOTAL	1.37E+08	1.37E+08	0	3.82E+14	0.00E+00	100

This scenario suggests that some alternative target may be in order as per discussion in Section 1. With a different definition for the target for allocation scenarios, the results suggest that an alternative scenario focused on land-based loads would allow for a smaller reduction of the number of livestock deposition in streams. However, the most common Best Management Practice to eliminate in-stream deposition is streamside fencing. Although portable fencing to coincide with a stream discharge sufficient to assimilate the increased fecal loads, may be theoretically possible, it was discounted as a viable current alternative. Additionally, since the relative difference in impact of land-based to directly deposited sources for this situation is very large, the relative decrease in reduction of livestock access would be small.

6. IMPLEMENTATION

6.1 TMDL Implementation Process

The goal of this TMDL is to establish a three-step path that will lead to expeditious attainment of water quality standards. The first step in this process was to develop an implementable TMDL. The second step is to develop a TMDL implementation plan, and the final step is to implement the TMDL and attain water quality standards.

Section 303(d) of the Clean Water Act (CWA) and current EPA regulations do not require the development of implementation strategies. However, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQ MIRA) directs VADEQ in section 62.1-44.19.7 to "develop and implement a plan to achieve fully supporting status for impaired waters". The Act also establishes that the implementation plan shall include that date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated cost, benefits and environmental impact of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process". The listed elements include implementation actions/management measures, time line, legal or regulatory controls, time required to attain water quality standards, monitoring plan and milestones for attaining water quality standards.

Since this TMDL consists primarily of NPS load allocations, VADCR will have the lead for the development of the implementation plan. Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of VADEQ, VADCR and other cooperating agencies.

Once developed, VADEQ intends to incorporate the TMDL implementation plan into the Roanoke River Water Quality Management Plan, in accordance with the CWA's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and VADEQ, VADEQ also submitted a draft Continuous Planning Process to EPA in which VADEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. In response to the federal Clean Water Action Plan, Virginia developed a Unified Watershed Assessment that identifies watershed priorities. Watershed restoration activities, such as TMDL implementation, within these priority watersheds are eligible for Section 319 funding. Increases in Section 319 funding in future years will be targeted towards TMDL implementation and watershed restoration. Other funding sources for implementation include the USDA's CREP program, the State's revolving loan program, and the VA Water Quality Improvement Fund.

6.2 Wildlife Contribution

VADEQ and VADCR have developed fecal coliform TMDLs for a number of impaired waters in the State. In some of the streams, as is the case for the Upper Blackwater River, fecal coliform bacteria counts contributed by wildlife result in standards violations, particularly during base flow conditions. Wildlife densities obtained from the Department of Game and Inland Fisheries and analysis or “typing” of the fecal coliform bacteria show that the high densities of muskrat, beaver, and waterfowl are responsible for the elevated fecal bacteria counts in these streams.

6.2.1 Designated Uses

All waters in the Commonwealth have been designated as "primary contact" for the swimming use regardless of size, depth, location, water quality or actual use. The fecal coliform bacteria standard is described in 9 VAC 25-260-170 and on page 1–3 in Section 1 of this report. This standard is to be met during all stream flow levels and was established to protect bathers from ingestion of potentially harmful bacteria. However, many headwater streams are small and shallow during base flow conditions when surface runoff has minimal influence on stream flow. Even in pools, these shallow streams do not allow full body immersion during periods of base flow. In larger streams, lack of public access often precludes the swimming use.

Base flow conditions of a stream occur at a higher frequency than flow conditions influenced by precipitation runoff events. As a result, the vast majority of the water quality sampling in the watershed used to determine the impairment occurred during base flow conditions. Therefore, a critical period for modeling to insure the attainment of water quality standards is during base flow conditions with little or no storm runoff.

In the TMDL public participation process, the residents in these watersheds often report that " people do not swim in this stream.” It is obvious that many streams within the state are not used for recreational purposes. In many cases, insufficient depth of the streams along with other physical factors and lack of public accessibility do not provide suitable conditions for swimming or primary contact recreation.

6.2.2 TMDL Allocations

The wildlife contributions of fecal bacteria from muskrats, beavers, and waterfowl are at their highest counts during base flow conditions when there is little or no pollutant wash-off from the adjacent land areas. Therefore base flow events represent the critical condition because the allocations needed to attain water quality standards during these flow regimes insure that standards were met in all other flow ranges.

For many of these streams, even the removal of all of the sources of fecal coliform (other than wildlife) does not allow the stream to attain standards during these critical conditions (or low flows). TMDL allocation reductions of this magnitude are not realistic and do not meet EPA’s guidance for reasonable assurance. Based on the water quality modeling, many of these streams will not be able to attain standards without some reduction in wildlife. **Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards.** This is obviously an impractical action. Clearly, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL or any other federal and state water quality management programs.

6.2.3 Options for Resolution of Wildlife Issue

To address the wildlife problem, EPA and Virginia have developed a TMDL strategy that will provide the reasonable assurance necessary under EPA guidance. The first step in this strategy is to develop a phased approach for the attainment of water quality standards in the TMDL. The first phase is to select an interim reduction goal, such as the Stage I implementation target described below. This goal has been selected by the stakeholders in the watershed and Virginia for EPA's approval as part of the TMDL process. In the interim goal or target, the pollutant reductions contained in the allocation were made only on controllable sources identified in the TMDL, setting aside any reduction of wildlife. During the first implementation phase, all reductions from controllable sources called for in the TMDL allocation would be reduced to their appropriate levels. The first phase would be a labor-intensive process that could occur on an incremental basis. While the first phase is underway, Virginia would be working concurrently on the second phase to address the wildlife issue.

Following completion of the first phase reductions, the VADEQ would re-assess the streams to determine if water quality standards had been attained. This effort will also determine if the modeling assumptions and approaches are correct. If it were found that water quality standards are not met, the second phase allocations would be initiated at a level necessary to meet existing standards. In some cases, the effort may never have to go to the second phase.

The second phase of the TMDL will result in the attainment of water quality standards. This phase involves a number of components outlined below:

- EPA has recommended that all States adopt an *E. coli* or enterococci standard for fresh water and enterococci criteria for marine waters by 2003. EPA is pursuing the States' adoption of these standards because there is a stronger correlation between the concentration of these organisms (*E. coli* and enterococci) and the incidence of gastrointestinal illness than with fecal coliform. *E-coli* and enterococci are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination. The adoption of the *E. coli* and enterococci standard is scheduled for 2002 in Virginia.

- Recognizing that all waters in the Commonwealth are not used extensively for swimming, VA is currently looking at re-designation of the swimming use based on actual swimming frequency and risk assessment. The new designation of the swimming use could contain the following 4 levels:

- Designated bathing beach (currently all waters protected to this level),
- Moderate swimming,
- Low swimming, and
- Infrequent swimming.

Each of the four swimming use levels would have protection criterion based on risk analysis. The current high levels of protection would continue to be applied to waters in which people are more likely to engage in an activity that results in the ingestion of water. The primary contact recreational uses recommended above are from EPA's Ambient Water Quality Criteria for Bacteria, 1986.

The re-designation of the current swimming use may require the completion of a use attainability analysis. A Use Attainability Analysis (UAA), is a structured scientific assessment of the factors affecting the attainment of the use which may include physical, chemical, biological, and economic factors as described in the Federal Regulations. The stakeholders in the watershed, Virginia, and EPA will have an opportunity to comment on these special studies.

- Most states apply their water quality standards only to flows above a statistical low flow frequency that is defined as a 7-day average occurring once every 10 years (7Q10). However Virginia's fecal coliform bacteria standard is applied to all flows. Some head water streams have very minimal flow during periods of low precipitation or droughts. During such low flow events, the counts of fecal coliform bacteria deposited directly into the stream are concentrated because the small flow is unable to dilute the deposition of wastes. In order to attain standards during low flow conditions, it is necessary to reduce the amount of waste deposited directly to the stream. Sources of these wastes include cattle in-stream, wildlife in-stream, septic systems, and wastes conveyed directly to the stream from milking parlors. By applying the standard only to flows greater than 7Q10, the TMDL would not need to insure the attainment of standards during extreme drought flow conditions when stream flow falls below 7Q10.
- Another option that EPA allows for the states is to adopt site specific criteria based on natural background levels of fecal coliforms. The State must demonstrate that the source of fecal contamination is natural and uncontrollable by effluent limitations and BMPs.

6.3 Stage I Implementation Goal (excluding Wildlife)

Implementation of best management practices (BMPs) in the watersheds will occur in stages. The benefit of staged implementation is that it provides a mechanism for developing public support and for evaluating the adequacy of the TMDL in achieving the water quality standard. The stage I allocation requires a 100% reduction of uncontrolled residential discharges, a 50% reduction in septic system failures, 50% conversion of poor pasture to good pasture, and a 90% reduction in livestock direct deposition into streams (Tables 6.1 and 6.2). The reduction of fecal coliform deposition into the stream by livestock is critical to reducing the number of violations of the 1,000 cfu/100 ml instantaneous standard. The first stage of the implementation represents preliminary steps in achieving the final allocation as described above.

Table 6.1 Land-based nonpoint source load reductions in the Upper Blackwater impairment for Phase I allocation.

Land use	Total annual loading for existing run (cfu/yr)	Total annual loading for allocation run (cfu/yr)	Percent Reduction
Good Pasture	1.43E+16	1.72E+16	-20
Poor Pasture	4.50E+14	2.25E+14	50
Cropland	7.97E+16	7.97E+16	0
Forest	2.16E+14	2.16E+14	0
Urban	2.08E+14	2.08E+14	0.05
Farmstead	1.59E+13	1.59E+13	0.05
Livestock Access	1.67E+14	5.11E+14	-206
Loafing Lot	4.02E+14	4.02E+14	0

Table 6.2 Load reductions to direct nonpoint sources in the Upper Blackwater impairment for Phase I allocation.

Subw'shed	Wildlife (cfu/year)			Straight Pipes (cfu/year)		
	Existing load	Allocated load	% Red.	Existing load	Allocated load	% Red.
8	1.16E+12	1.16E+12	0	5.75E+11	0.00E+00	100
9	3.74E+11	3.74E+11	0	5.59E+11	0.00E+00	100
10	6.50E+11	6.50E+11	0	7.92E+11	0.00E+00	100
11	1.05E+12	1.05E+12	0	5.11E+11	0.00E+00	100
TOTAL	3.24E+12	3.24E+12	0	2.44E+12	0.00E+00	100

Subw'shed	Lateral Flow (cfu/year)			Livestock (cfu/year)		
	Existing load	Allocated load	% Red.	Existing load	Allocated load	% Red.
8	3.44E+07	3.44E+07	0	1.03E+14	1.03E+13	90
9	3.50E+07	3.50E+07	0	1.01E+14	1.01E+13	90
10	1.85E+07	1.85E+07	0	2.65E+13	2.65E+12	90
11	4.93E+07	4.93E+07	0	1.52E+14	1.52E+13	90
TOTAL	1.37E+08	1.37E+08	0	3.82E+14	3.82E+13	90

Strategies to accomplish the TMDL including the implementation of the stage I implementation plan are scheduled to start in July 2000. In developing the implementation plan, elements from both State and Federal guidance will be incorporated. Specifically, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act establishes that the implementation plan shall include the date of expected achievement water quality objectives, measurable goals, corrective actions necessary, and the associated costs, benefits and environmental impact of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 proposal, "Guidance for Water Quality-Based Decisions: The TMDL Process". These elements include implementation actions/management measures, time line, legal or regulatory controls, time required to attain water quality standards, monitoring plan, and milestones for attaining water quality standards.

Public participation during the implementation plan development process will include the formation of stakeholders committee and open public meetings. Public participation is critical to promote reasonable assurances that the implementation activities will occur. A stakeholders committee will have the expressed purpose of formulating the TMDL implementation plan. The major stakeholders were identified during the development of this TMDL. The committee will consist of, but not be limited to, representatives from the Department of Environmental Quality, Department of Conservation and Recreation, Department of Health, local agricultural community, local urban community, local governments, and the independent technical advisors from MapTech, Inc. This committee will have responsibility for identifying corrective actions that are founded in practicality, establish a time line to insure expeditious implementation and set measurable goals and milestones for attaining water quality standards.

The development of the implementation plan is expected to be an iterative process. Implementation of control measures will begin after the implementation plan development is completed, which is expected to cover a timeline of approximately seven months. Subsequent refinements will be made as the progress toward meeting milestones and the expressed TMDL goals is assessed. As practices are implemented, periodic analyses of water quality conditions will be conducted to evaluate the progress toward meeting end goals.

6.4 Follow-Up Monitoring

The Virginia Department of Environmental Quality will continue to monitor water quality in the Blackwater River watershed in accordance with its ambient monitoring program. After the percentage of violations of the instantaneous standard for fecal coliform has dropped to 10% or less, the monitoring frequency will be increased to allow assessment of water quality in comparison to the geometric mean standard for fecal coliform. VADEQ and VADCR will continue to use data from the ambient monitoring stations to evaluate reductions in fecal bacteria counts and the effectiveness of the TMDL in attaining and maintaining water quality standards.

6.5 Public Participation

A key element in the development of a TMDL is public participation. During the course of developing the TMDL for the Upper Blackwater, five meetings were held (Table 6.3). One meeting was semi-public, three were open to the public at large, and one was open to a select group of farmers. The first was convened on September 2 of 1999 at Ferrum College. Members of each stakeholders group were invited to participate in discussions outlining the development process and subsequent meetings. This meeting focused on all fecal coliform TMDLs within the Blackwater River. Three additional meetings were held for the public at large, and focused on the upper four impairments on the Blackwater River. A basic description of the TMDL process and the agencies involved was presented at the first of the three public meetings. During the second public meeting, details of the hydrologic calibration and pollutant sources were presented. The final model simulations and the TMDL load allocations were presented during the final public meeting. All meetings were advertised in the *Virginia Register* and the *Franklin News Post*. Additionally, the last two meetings were advertised through the local cable television network. Presentation materials were distributed at each meeting.

Comments from the meetings ranged from the simplistic view of resolving the violations of the *beneficial use standard* by *posting "no trespassing" signs at the waters edge,* to the more insightful view that *maybe we shouldn't be importing fecal coliform* in reference to biosolids used within the watershed. Few comments were made that specifically addressed the development approach and/or the data utilized. Of those made, the spatial identification of septic systems and their failure rates were of concern. Regarding spatially locating septic systems, all available data were considered. The location of septic system are documented on paper copies of the issued permits and archived with the Franklin County Health Department. It was considered impractical to compile a digital database locating the septic systems given the time constraints of this study. It should also be noted that these records are incomplete due to the age of some systems and when permitting was initiated. In order to spatially distribute septic systems, 1990 census block group data were used (USCB, 1990). One question arose from the proposed use of 9.4% for a failure rate of septic systems. The 9.4% was obtained from the local agency that issues permits for septic system installations and repairs, and was a function of the number of permits issued for septic system repairs. After reviewing the concern with agency personnel, it was concluded the 9.4% did not reflect the failure rate as defined by the number of permits issued for septic failures divided by the total number of septic systems. The failure rate was revised to 1.3%, which incorporated this definition.

In addition to the open public meetings, MapTech, Inc. conducted a meeting on November 22, 1999 with twelve local farmers. The farmers were identified and assembled by the Franklin County Farm Bureau. The intent of the meeting was to gain information of local farming practices that impact the delivery of fecal coliform to the streams. MapTech, Inc. personnel conducted a survey of agricultural practices at the meeting, and the survey results formed much of the basis of the modeling described in the earlier sections.

In addition to the more direct public presentations described above, two special one-hour programs and the public meeting held on February 16, 2000 were video-taped and televised. These programs were available to 8500 county households with cable television access, as well as local institutions such as Ferrum College.

Table 6.3 Public participation in the TMDL development for the Upper Blackwater watershed.

Date	Location	Attendance[1]	Format
09/02/1999	Ferrum College; Ferrum, Va.	26 (38% from the community)	Stakeholders by invitation
11/04/1999	Rocky Mount Town Hall; Rocky Mount, VA	34 (70% from the community)	Open to public at large
11/22//1999	Franklin Co. Farm Bureau, Rocky Mount, VA	12 farmers, 5 project personnel	Local farmers by invitation
01/03/2000	Gabriel Communications; Redwood, VA	8,500 households in Franklin County, VA plus local institutions (e.g. Ferrum College) televised live and broadcast 10 times during the following week	One hour local cable program "Rise and Shine" hosted by Brian Duvall
02/16/2000	Rocky Mount Town Hall; Rocky Mount, VA	38 (82% from the community)	Open to public at large
		8,500 households in Franklin County, VA plus local institutions (e.g. Ferrum College) televised 5 times during the following two weeks	Video-taped for local cable network
03/08/2000	Gabriel Communications; Redwood, VA	8,500 households in Franklin County, VA plus local institutions (e.g. Ferrum College) televised live and broadcast 10 times during the following week	One hour local cable program "Rise and Shine" hosted by Steve Oakes
03/15/2000	Ferrum College; Ferrum, VA	56 (68% from the community) 97 (from head count) (85% from the community)	Open to public at large
		8,500 households in Franklin County, VA plus local institutions (e.g. Ferrum College) televised 5 times during the following two weeks	Video-taped for local cable network

[1] The number of attendants is estimated from sign up sheets provided at each meeting. These numbers are known to under estimate the actual attendance.

APPENDIX: A

FECAL COLIFORM DISTRIBUTIONS FOR EACH SAMPLING STATION IN THE UPPER BLACKWATER IMPAIRMENT

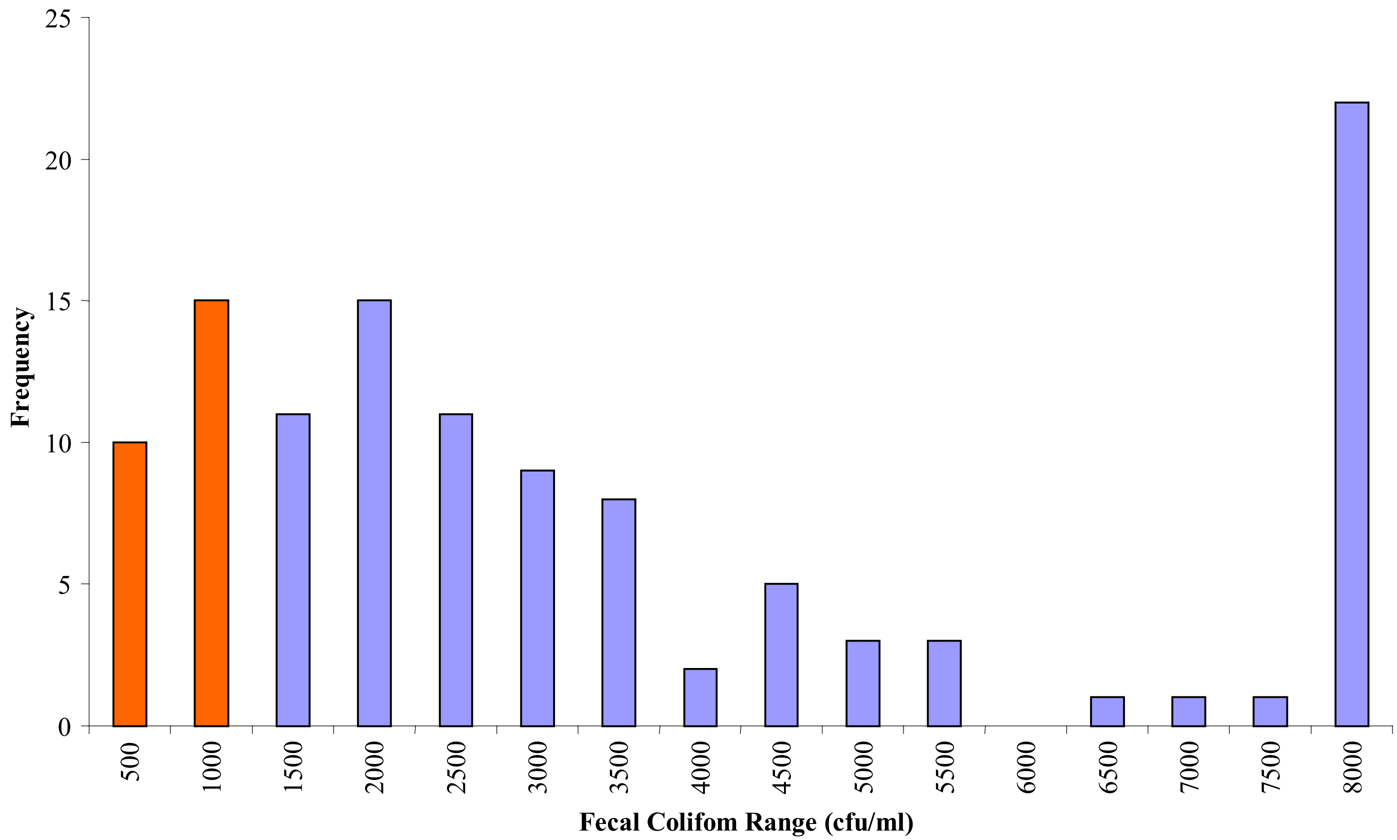

Figure A.1 **Frequency analysis of fecal coliform concentrations at VADEQ water quality monitoring station 4ABWR061.20 in the Upper Blackwater impairment.**

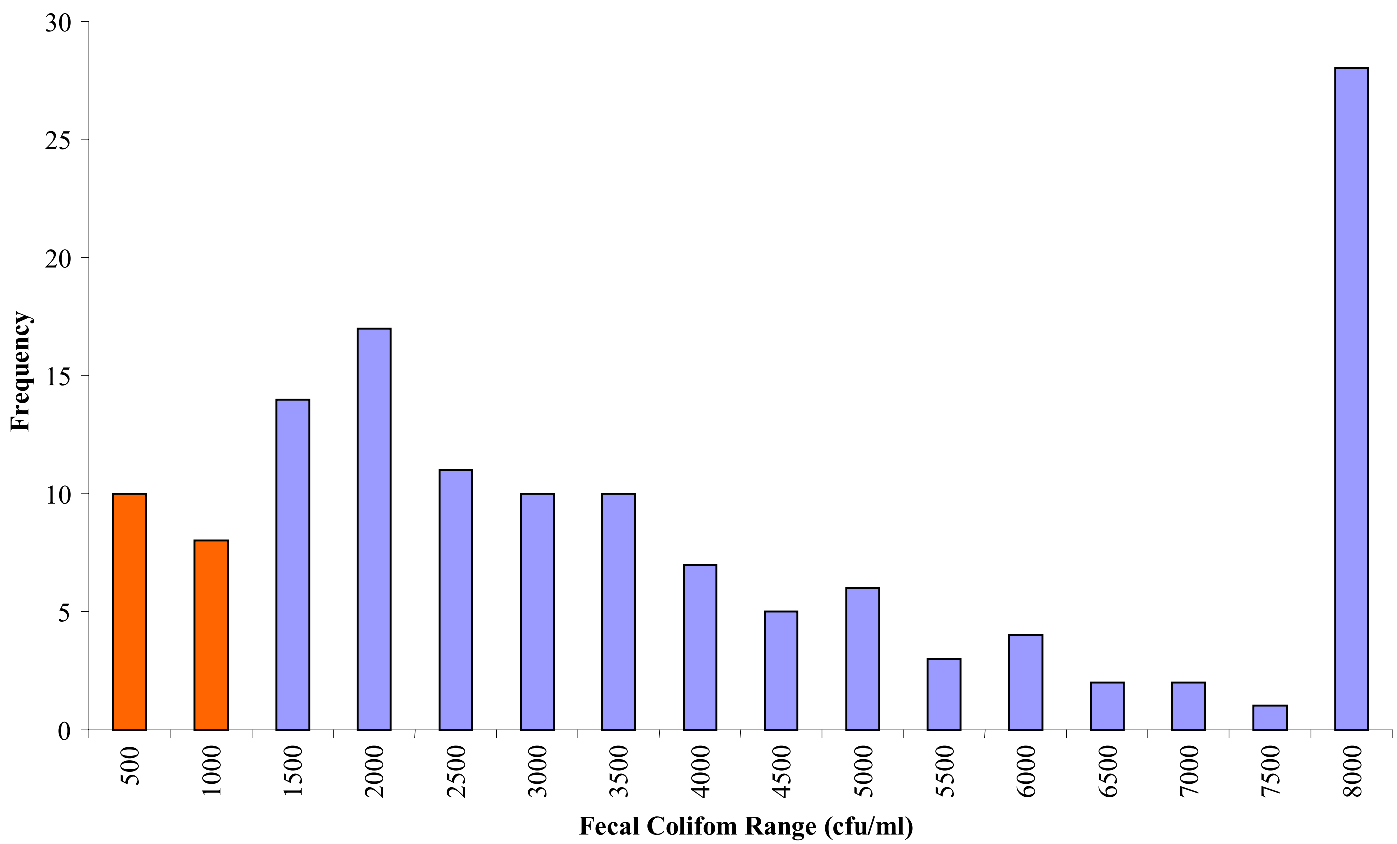

Figure A.2 Frequency analysis of fecal coliform concentrations at VADEQ water quality monitoring station 4ABWR054.81 in the Upper Blackwater impairment.

APPENDIX: B

FECAL COLIFORM LOADS IN EXISTING CONDITIONS

Table B.1 Current conditions (1999) of land applied fecal coliform load for Upper Blackwater impairment.

	Good Pasture cfu/ac*day	Poor Pasture cfu/ac*day	Cropland cfu/ac*day	Forest cfu/ac*day	Urban cfu/ac*day	Farmstead cfu/ac*day	Livestock Access cfu/ac*day	Loafing Lot cfu/ac*day
January	8.40E+10	8.71E+09	6.41E+10	5.85E+08	1.44E+10	4.80E+09	1.26E+10	8.51E+10
February	8.42E+10	8.71E+09	7.18E+10	5.85E+08	1.44E+10	4.80E+09	1.27E+10	8.51E+10
March	8.28E+10	8.53E+09	6.07E+11	5.85E+08	1.44E+10	4.80E+09	2.47E+10	8.51E+10
April	8.18E+10	8.36E+09	6.07E+11	5.38E+08	1.44E+10	4.80E+09	3.67E+10	8.51E+10
May	8.22E+10	8.36E+09	6.07E+11	5.38E+08	1.44E+10	4.80E+09	3.67E+10	8.51E+10
June	2.54E+11	1.75E+10	6.57E+08	5.38E+08	1.44E+10	4.80E+09	4.87E+10	8.51E+10
July	2.55E+11	1.75E+10	7.04E+08	4.91E+08	1.44E+10	4.80E+09	4.87E+10	8.51E+10
August	2.55E+11	1.75E+10	7.04E+08	4.91E+08	1.44E+10	4.80E+09	4.87E+10	8.51E+10
September	8.28E+10	8.36E+09	1.86E+11	4.91E+08	1.44E+10	4.80E+09	3.67E+10	8.51E+10
October	8.46E+10	8.53E+09	6.18E+11	4.91E+08	1.44E+10	4.80E+09	2.47E+10	8.51E+10
November	8.40E+10	8.53E+09	6.07E+11	4.91E+08	1.44E+10	4.80E+09	2.46E+10	8.51E+10
December	8.51E+10	8.71E+09	6.41E+10	5.85E+08	1.44E+10	4.80E+09	1.26E+10	8.51E+10

Table B.2 Monthly, direct-deposition, fecal coliform loads in each reach under current conditions.

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
8	Wildlife	1.98E+09	1.98E+09	1.98E+09	1.98E+09	1.98E+09	1.98E+09
	Human	1.58E+09	1.58E+09	1.58E+09	1.58E+09	1.58E+09	1.58E+09
	Livestock	1.12E+11	1.12E+11	2.25E+11	3.37E+11	3.37E+11	4.49E+11
9	Wildlife	6.43E+08	6.43E+08	6.43E+08	6.49E+08	6.49E+08	6.49E+08
	Human	1.53E+09	1.53E+09	1.53E+09	1.53E+09	1.53E+09	1.53E+09
	Livestock	1.10E+11	1.10E+11	2.21E+11	3.31E+11	3.31E+11	4.41E+11
10	Wildlife	1.12E+09	1.12E+09	1.12E+09	1.11E+09	1.11E+09	1.11E+09
	Human	2.17E+09	2.17E+09	2.17E+09	2.17E+09	2.17E+09	2.17E+09
	Livestock	2.96E+10	3.03E+10	5.86E+10	8.69E+10	8.69E+10	1.15E+11
11	Wildlife	1.80E+09	1.80E+09	1.80E+09	1.79E+09	1.79E+09	1.79E+09
	Human	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09
	Livestock	1.67E+11	1.67E+11	3.33E+11	4.99E+11	4.99E+11	6.65E+11

Reach	Source	Jul (cfu/day)	Aug (cfu/day)	Sep (cfu/day)	Oct (cfu/day)	Nov (cfu/day)	Dec (cfu/day)
8	Wildlife	1.97E+09	1.97E+09	1.97E+09	1.97E+09	1.97E+09	1.98E+09
	Human	1.58E+09	1.58E+09	1.58E+09	1.58E+09	1.58E+09	1.58E+09
	Livestock	4.49E+11	4.49E+11	3.37E+11	2.25E+11	2.25E+11	1.12E+11
9	Wildlife	6.56E+08	6.56E+08	6.56E+08	6.56E+08	6.56E+08	6.43E+08
	Human	1.53E+09	1.53E+09	1.53E+09	1.53E+09	1.53E+09	1.53E+09
	Livestock	4.41E+11	4.41E+11	3.31E+11	2.21E+11	2.21E+11	1.10E+11
10	Wildlife	1.11E+09	1.11E+09	1.11E+09	1.11E+09	1.11E+09	1.12E+09
	Human	2.17E+09	2.17E+09	2.17E+09	2.17E+09	2.17E+09	2.17E+09
	Livestock	1.15E+11	1.15E+11	8.69E+10	5.86E+10	5.76E+10	2.96E+10
11	Wildlife	1.79E+09	1.79E+09	1.79E+09	1.79E+09	1.79E+09	1.80E+09
	Human	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09
	Livestock	6.65E+11	6.65E+11	4.99E+11	3.33E+11	3.33E+11	1.67E+11

Table B.3 Existing annual loads from land-based sources for Upper Blackwater River impairment.

Source	Good Pasture (cfu/yr)	Poor Pasture (cfu/yr)	Cropland (cfu/yr)	Forest (cfu/yr)	Urban (cfu/yr)	Farmstead (cfu/yr)	Livestock Access (cfu/yr)	Loafing Lot (cfu/yr)
Pets								
Dogs	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.05E+14	1.47E+13	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.35E+08	9.72E+06	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.05E+14	1.47E+13	0.00E+00	0.00E+00
Human								
Failed Septic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.34E+11	1.61E+10	0.00E+00	0.00E+00
Livestock								
Dairy	1.41E+16	4.39E+14	7.95E+16	0.00E+00	0.00E+00	0.00E+00	1.63E+14	4.00E+14
Beef	9.72E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E+12	0.00E+00
Sheep	3.78E+09	6.96E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Goat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Horse	1.53E+12	0.00E+00	0.00E+00	3.27E+10	0.00E+00	0.00E+00	9.80E+09	0.00E+00
Donkey	4.96E+10	9.11E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	1.42E+16	4.40E+14	7.95E+16	3.27E+10	0.00E+00	0.00E+00	1.64E+14	4.00E+14
Wildlife								
Raccoon	2.56E+13	7.09E+12	1.11E+14	8.68E+13	1.56E+12	7.26E+11	1.36E+12	1.06E+12
Muskrat	2.84E+12	1.04E+12	1.38E+13	2.32E+13	2.75E+11	2.59E+11	8.75E+11	0.00E+00
Deer	3.22E+12	5.52E+11	3.86E+13	8.44E+13	3.57E+11	1.74E+10	1.36E+11	1.00E+10
Turkey	2.64E+08	1.91E+07	7.21E+08	3.58E+09	0.00E+00	0.00E+00	6.25E+05	1.76E+05
Goose	7.91E+07	3.17E+07	2.15E+08	2.96E+08	2.05E+07	2.99E+06	4.67E+06	1.72E+06
Duck	7.88E+07	3.16E+07	2.14E+08	2.95E+08	2.04E+07	2.98E+06	4.66E+06	1.72E+06
Unquantifiable	3.52E+12	9.65E+11	1.82E+13	2.16E+13	2.43E+11	1.11E+11	2.63E+11	1.19E+11
Total	3.52E+13	9.65E+12	1.82E+14	2.16E+14	2.43E+12	1.11E+12	2.63E+12	1.19E+12

Table B.4 Existing annual loads from direct-deposition sources for Upper Blackwater River impairment.

Source	Fecal Coliform Load (cfu/yr)
Human	
Straight Pipes	2.44E+12
Lateral Flow	1.37E+08
Total	2.44E+12
Livestock	
Dairy	3.79E+14
Beef	3.16E+12
Sheep	0.00E+00
Goat	0.00E+00
Horse	2.29E+10
Donkey	0.00E+00
Total	3.82E+14
Wildlife	
Raccoon	6.56E+11
Muskrat	2.21E+12
Beaver	1.83E+09
Deer	7.14E+10
Turkey	2.57E+06
Goose	1.86E+07
Duck	2.81E+07
Unquantifiable	2.94E+11
Total	3.24E+12

APPENDIX: C

ENVIRONMENTAL PROTECTION AGENCY TMDL REVIEW AND SUBSEQUENT RESPONSE TO REVIEW

From: Gold.Peter@epamail.epa.gov
Date: Fri, 14 Apr 2000 11:41:03 -0400
To: mshelor@dcr.state.va.us
Cc: Henry.Thomas@epamail.epa.gov

Mike,

As per our conversation I have listed some of the items we would like to discuss during next week's conference call.

1) Reductions in Wildlife Contribution (Specifically how will this be accomplished)

   a)Wouldn't comparable reductions in the land application of wastes be easier to achieve
   b)The fecal coliform production rates for wildlife in these reports appear to be significantly larger than those in other reports

2) How the ability to control less than 1% (cattle Instream and Wildlife) of the loading will allow these wasters to attain WQS
   a) The sensitivity analysis (figure 5.1), seems to show that reductions in the land application of wastes have a dramatic affect on FC loading
   b) Figure 5.2 (NF blackwater), seems to demonstrate that reductions in the land application of wastes are needed
   c) Does this model address violations occurring during high storm events

3) What was the Die-off equation?

4) Explain differences in Table 5.1 and Table B.1

5) Review the relationship between Figure 5.5 and Figure 5.4

Please contact me if you have any questions. Thanks

MapTech's Response to EPA's Topics of Concern
April 18, 2000

1) Reductions in Wildlife Contribution (Specifically how will this be accomplished)

This is a policy issue to be addressed by DEQ and DCR. Two methods of addressing this problem include improved wildlife management and/or a change in the WQ standard.

a)Wouldn't comparable reductions in the land application of wastes be easier to achieve

Modeling scenarios were conducted excluding all sources with the exception of wildlife. These simulations showed violations of the 30 day geometric mean standard during low flows, specifically, the lowest flows in twenty years. It was these critical conditions that dictated the allocation scenarios and thus the level of reductions. Under these conditions no runoff was produced and thereby no fecal coliform originating from the land were delivered to the stream.

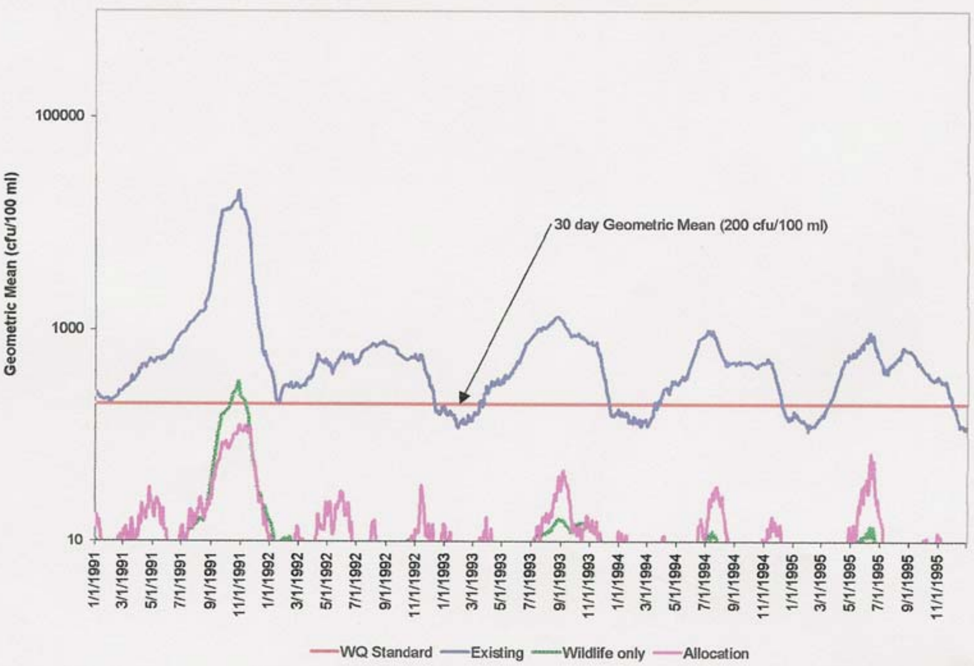

Figure 1. Modeling scenarios comparing existing conditions with wildlife only and the TMDL allocation loads.

As can be seen in Figure 1, the geometric mean was violated during September and November

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of 1991 with only wildlife as a source.

b)The fecal coliform production rates for wildlife in these reports appear to be significantly larger than those in other reports

Wildlife fecal coliform production rates were developed from; a)accounting for several wildlife species, including raccoon, muskrat, beaver, deer, turkey, goose, and duck, b) locally-collected samples analyzed to determine fecal coliform densities within species-specific fecal matter and c) literature values for fecal matter production rates. Fecal coliform densities values , if they exist, vary greatly in the literature (Table 1). These variations are attributed to numerous factors including regional factors, such as food sources, that impact the well being of the animal population. To address these factors, samples were collected and analyzed for fecal coliform densities from sources within the watersheds.

In comparison, other TMDLs (e.g. Muddy Creek, Middle Fork Holston) developed in Virginia, a) considered fewer species (i.e. only deer were considered for the Muddy Creek and deer and geese for the Middle Fork Holston TMDLs), b) fecal densities were derived from literature values and c) fecal production rates were derived from literature sources.

Fecal typing conducted during the course of this study confirmed the significance of the wildlife contribution.

Table 1. Fecal coliform densities.

Type	Locally Collected Average (FC/gm)	Reported Average (FC/gm)	Reported Standard Dev. (FC/gm)
Dairy (1400 lb)	427,667	1,844,073 (3)	3,329,577
Beef (800 lb)	45,500	4,936,959 (3)	4,557,193
Pig (135 lb)		2,097,755 (3)	1,415,985
Sheep (60 lb)	15,000	11,013,216 (3)	6,607,930
Horse (1000 lb)	185,000	18,139 (3)	5,615
Duck (3 lb)		16,219,463 (3)	16,219,463
Chicken (4 lb)	1,800,000	1,170,154 (3)	313,188
Turkey (15 lb)		290,187 (3)	
Dairy Separator	32,000 cfu/100ml		
Dairy Storage Pit	1,200 cfu/100ml		
Deer	3,300,000	4,100,000 (1)	2.4E2 to 5.8E7
Turkey		290,187*	
Raccoon	13,100,000	250,000 (2)	
Muskrat	1,900,000	250,000 (2)	
Beaver		1,000 (2)	
Goose	320	220,000 (1)	1.3E2 to 6.4E6
Duck	490	437,000 (2)	
Rabbits		20 (4)	
Chipmunk		148,000 (4)	
Mice		330,000 (4)	

*- number is for domestic animal.
1) Hagedorn, C.; 2) Yagow, E.; 3) ASAE; 4) Geldreich, E

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2)How the ability to control less than 1% (cattle Instream and Wildlife) of the loading will allow these waters to attain WQS

It is key to remember that the standard is based on concentration not loadings. Small loads under low flow conditions can and do represent significantly greater concentrations than large loads under high flow conditions.

It is also important to remember even though direct deposition of fecal matter into the stream represents a small fraction of the total fecal matter being produced within the watershed, it does represent a significant load being delivered to the stream. Figure 5.1 illustrates that approximately 25 percent of the total annual load leaving the stream impairment is attributed to the livestock direct access.

a) The sensitivity analysis (figure 5.1), seems to show that reductions in the land application of wastes have a dramatic affect on FC loading

Figure 5.1 illustrates the annual loading attributed to the different sources (i.e. land applied waste, livestock direct deposition, and straight pipes) irrespective of instream concentrations. Under wet weather conditions total loadings may be significant in magnitude but the corresponding flow conditions allow the stream to assimilate the pollutant (fecal colliform). In other words "dilution is the solution to pollution"

b) Figure 5.2 (NF Blackwater), seems to demonstrate that reductions in the land application of wastes are needed

While Figure 5.2 shows that a significant reduction in the 30-day geometric mean concentration can be achieved through a reduction in the land-based sources during wet seasons, it is important to remember that the geometric mean is not an additive quantity. Therefore a reduction in the land-based sources is not necessary in order to meet the standard. Since violations during the dry seasons were not influenced by the land-based sources, reductions in the direct deposition sources were necessary to reach the standard. In meeting the standard during the dry seasons, reductions were sufficient so as not to require a reduction in land-based sources during the wet seasons.

c) Does this model address violations occurring during high storm events

Yes, as can be seen in Figure 5.5 throughout the four years of simulated precipitation and flow conditions the standard was met with the allocated loads.

3) What was the Die-off equation?

Die-off of fecal coliform can be handled implicitly or explicitly. For land-applied fecal matter, (mechanically applied and deposited directly) die-off was addressed implicitly through monitoring and modeling. Samples of collected waste (i.e. dairy waste from loafing areas) were locally collected and analyzed prior to being land-applied. Therefore, die-off is implicitly accounted for through the sample analysis. Die-off occurring in the field was represented implicitly through model parameters such as the maximum storage and the 90% waste off rate, which were adjusted during the calibration of the model. These parameters were assumed to represent not only the delivery mechanisms but the bacteria die-off as well. Once the fecal coliform entered the stream, the general decay module of HSPF was incorporated, thereby explicitly addressing the die-off rate. The general decay module uses a first order decay function to simulate die-off.

4) Explain differences in Table 5.1 and Table B.1

Table B.1 represents the current land-applied loads, and is intended to give the reader an idea of the spatial and temporal distribution of the land-applied fecal coliform. Data for this table are presented as daily loads/acre , as required for HSPF. Table 5.1 represents the land-applied fecal coliform load reduction for the final allocation by land use. Data are presented as annual loads. It simply identifies the land use where reductions (or increases) in the loads are made. This table was derived from Table B.1 by simply multiplying by the number of days in a given month with the month's and land use's daily load and the land use area, repeating this for all months and summing the monthly results by land use.

5) Review the relationship between Figure 5.5 and Figure 5.4

Figure 5.4 illustrates the reductions in the geometric mean given a reduction in the direct deposition of fecal matter by livestock. The modeling period was January through December of 1995. It is part of the sensitivity analysis performed and should be reviewed in that context. The seasonal impact on the geometric mean should be noted. The maximum impact on the geometric mean occurs from April through June, the wet season (Table 2.4) The next greatest impact occurs between August and October, the dry season as indicated by table 2.4.

Figure 5.5 shows the geometric mean of the existing conditions, as well as, that of the TMDL load allocation. The modeling period was January, 1991 through December of 1995. The TMDL allocation represents reductions in all direct deposition sources (i.e. straight pipes, livestock and wildlife). Once again the seasonal variation of the geometric mean should be noted. Annually, the maximum geometric mean, under existing conditions, occur during late *summer to early fall. As indicated by Table 2.4 this is the low flow season of the streams. The lowest geometric mean occurs annually between March and May, the wet season (Table 2.4).*

Keeping in mind that the geometric mean concentration is not additive, one can see the impact of reducing livestock access in both figures. Consider June 1995. Figure 5.4 shows that a 100% reduction in livestock access results in approximately a 1000 cfu/100 ml reduction in the geometric mean. Figure 5.5 show a corresponding order of magnitude reduction in the geometric mean given the TMDL allocation scenario.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
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July 06, 2000

Mr. Mike Shelor
Virginia Department of Conservation and Recreation
203 Governor Street, Suite 213
Richmond, Virginia 23219-2094

Dear Mr. Shelor:

The Environmental Protection Agency (EPA) has been conducting its evaluation of the TMDLs for the Blackwater River. EPA would like further documentation on several issues associated with these documents. In order to evaluate the model more efficiently, EPA would like to have a copy of the observed water quality data associated with these TMDLs and a working copy of the model. There appears to be a disparity in the fecal coliform production rates between the organisms evaluated in these TMDLs (geese vs racoon). Please provide some rationale for this variability in production rates.

Based on Figures 4.12 and 4.13 it appears as though the water quality calibration is missing several of the observed spikes in fecal coliform concentrations. EPA would like the Commonwealth to explain the 48 hr moving average that was used in these figures and justify why they believe that these calibrations accurately reflect the observed data. Do the peaks in the observed data occur during low or high flow events. Please specifically discuss how high flow events affect the model (is the fecal coliform being diluted out or does wash off cause exceedances of the standard).

EPA has been discussing how to best justify implementation of a TMDL that includes large reductions in wildlife. Because we do not believe it can be expected to reduce wildlife by 60% or more, a phased approach to the implementation may be necessary. Our initial thoughts are that all of the reductions which were called for in the TMDL (with the exception of wildlife) would be reduced in phase one of the implementation plan. After the completion of phase 1 of the implementation plan the State would evaluate the stream with a rigorous sampling initiative taking samples during low and high flow events. The sampling would be used to verify or improve the modeling assumptions, to determine if standards are being met, and if wildlife or any other reductions are necessary. The Commonwealth will review its standards to address contributions of fecal coliform from wildlife.

We would be interested on your views of this approach. Please feel free to contact Peter Gold at 215-814-5236 or gold.peter@epa.gov, if you have any questions or comments.

Sincerely,

Thomas Henry
TMDL Program Manager

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July 18, 2000

Mr. Mike Shelor
Virginia Department of Conservation and Recreation
203 Governor Street, Suite 213
Richmond, Virginia 23219-2094

Dear Mr. Shelor:

In response to the Environmental Protection Agency's (EPA) request for further documentation on several issues associated with the TMDLs for the Blackwater River the following is provided. I have presented EPA's request in italics, directly quoted from Mr. Thomas Henry's letter to you dated July 7, 2000.

From paragraph one, Mr. Henry states: ***In order to evaluate the model more efficiently, EPA would like to have a copy of the observed water quality data associated with these TMDLs.***

I believe this information is best obtained from DEQ. However, we will certainly be happy to supply this information if needed.

Continuing with Mr. Henry's sentence: ***and a working copy of the model.***

We will be more than happy to provide another "working copy of the model". This copy is provided on CD via separate mail. Please note, as indicated in section 4.1 of the TMDL documents, HSPF was used rather than BASINS. Specifically, we used HSPEXP which incorporates version 11 of HSPF. We chose this option rather than BASINS because we had much more detailed GIS map layers and associated data than available in BASINS.
For this application, the use of HSPF, HSPEXP and ANNIE afforded us more flexibility and efficiency when working with the Blackwater database. The detailed subdivisions that we utilized resulted in some time of concentrations being less than thirty minutes which prompted us to conduct simulations over a fifteen minute time step. This resulted in very large output files (i.e. discharge and fecal colform concentrations) which required additional tools for analysis. If the problems are associated with running this group of models, please let me know and we will be more than happy to provide assistance in doing so. We have included a copy of the executable code for HSPEXP on the CD. Instructions for the models and HSPEXP can be found in the *Readme* files provided on the CD.

Mr. Henry continues in paragraph one: ***There appears to be a disparity in the fecal coliform production rates between the organisms evaluated in these TMDLs (geese vs racoon). Please provide some rationale for this variability in production rates.***

It should be understood, that the fecal coliform production rates are the products of fecal coliform

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densities (i.e. cfu's per unit weight of fecal matter) and fecal matter production rates per species (i.e. weight of fecal matter per unit species per unit time). It is well documented that fecal coliforms production rates vary between, as well as, within species (e.g. ASAE 1998, Alderisio. and DeLuca 1999,Geldreich 1978,Kator and Rhodes 1996, Valiela et al. 1991, and WV DEP and EPA 1997). It is generally accepted in the scientific community, that there are regional impacts (e.g. food rations) on fecal densities within a species. Production rates for the Blackwater TMDLs were developed from fecal coliform densities measured from samples collected in the study area and species-specific fecal matter production rates obtained from the literature or measured. The use of values obtained from the study area were considered more defensible in terms of both public and scientific review.

Specifically addressing racoon and geese, the range of fecal density literature values found were 2.5 E05 to 1.0 E09 and 1.3 E02 to 2.42 E07 cfu/g for racoon and geese, respectively. The values used for the Blackwater River TMDLs (1.3 cfu/g E07 for racoon and 3.2 E02 cfu/g for geese) were certainly within these ranges. Because of the variability within the literature values we considered data from the locally (i.e. Blackwater River drainage) collected samples to be more relevant than those listed in the literature.

From paragraph two, Mr. Henry states: ***Based on Figures 4.12 and 4.13 it appears as though the water quality calibration is missing several of the observed spikes in fecal coliform concentrations.***

As you know, we have submitted four TMDLs addressing the four impairments in the headwaters and Blackwater River. Figures 4.12 and 4.13 from the North Fork, South Fork and the Upper Segment TMDL documents depict modeling results from the validation runs (VR), for the headwaters and impairment outlet, respectively. Where as, Figures 4.12 and 4.13 from the Middle Segment document depict assessments of the calibration simulation (CA) by overlaying observed data onto max/min plots. I would suggest reviewing the documents for detailed descriptions of these plots.

With regard to the VR plots, the simulations depicted were conducted without modification of the model parameters in order to assess the appropriateness of the calibrated model parameters with climatic conditions other than those used during the calibration runs. As pointed out by Mr. Henry, the model simulations do in fact miss several of the observed spikes in fecal coliform concentrations. These misses are characterized by both underestimates and overestimates. With variation at a sampling point, as high as, 4200 % between duplicate samples taken at the same location and time (3-15 minutes apart), the peaks for most instances unknown because of detection limits used, a homogeneous assumption assumed for the cross-section, in addition to model and information detail issues, we considered the validation run an acceptable simulation of reality.

With regard to the CA plots, the maximum and minimum modeled concentrations depicted were determined from a 48 hour window centered on a single observed value. These plots were

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developed to respond to errors associated with temporal shifts in the modeling (e.g. where the hydrology calibration lags or leads the observed hydrographs). With an ideal fit, the observed data would be bound by the maximum and minimum modeled values. Once again there were exceptions to this ideal case. Some observations fell outside these limits. These were attributed to the censuring of data, natural variability in sample analysis (e.g. some of the observed values reflect analysis of field duplicate samples with significant variability), unknown spatial variability in rainfall distribution, and modeling uncertainty. However, generally, the observed values were bound by the limits.

Continuing, Mr. Henry requests: ***EPA would like the Commonwealth to explain the 48 hr moving average that was used in these figures***

The 48 hr moving average depicted in the VR plots, portrays the 48 hour moving window average of the modeled fecal coliform concentrations. It was presented solely for the viewer, to depict the general trends. These trends were not used in any other way within the TMDL analysis.

and justify why they believe that these calibrations accurately reflect the observed data.

The determination of the goodness of fit of the model simulations of fecal coliform as compared with the observed data is difficult to precisely quantify because of many complex and generally unknown factors. For example, limited number of observations, type of sampling (grab sample for a point/stream location rather then stream cross-section composite), the transport/delivery mechanisms and the spatial distribution of the pollutant and the censuring of data, both high and low, are factors that limit our ability to quantify the goodness of fit. Generally, these determinations are more subjective than objective and made using best professional judgment after careful evaluation of simulated and corresponding observed data and seasonal response to storm and base flows where observed data do not exist. This approach is supported from an extensive review of literature that shows an absence of quantitative measures of goodness of fit. Professional judgment becomes important in these type of evaluations (i.e. situations with limited observed quality data with unknown spatial and temporal error and complex system interactions). For example, relative conclusions such as, *"... appears to provide a good fit"* (EPA, 2000) and *"... closely matched observed data"* (WV DEP and EPA , 1997) are common and generally accepted for describing a model's goodness of fit at the completion of calibration and subsequent validation analysis.

Our evaluation of simulation results included three components and consisted of both subjective and objective criteria: 1) visual interpretation of graphical comparisons of simulated and observed data, 2) visual interpretation of graphic summary of data for selected time interval before and after observed data point, and 3) average standard error.

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Visual interpretation of graphical comparisons of simulated and observed data: Visual interpretation involved among other things an evaluation of how well simulated fecal coliform counts for 15- minute time intervals relate to corresponding observed point data. The evaluation involved examining trends, consistency, and maximum-minimum values during high and low flows, seasonal patterns and spatial variability over the calibration and subsequent validation time period . Since only limited observed data existed, trends in modeled data during low and high flow both before and after each observed time period were also carefully examined. The maximum instantaneous values were evaluated based on very limited uncensored data available from previous research studies conducted in the Blackwater River watershed. These research results provided limited insight into probable maximum values. During the calibration phase, the process was iterative in that many simulation runs were made that involved the adjustment of appropriate model parameters to improve the overall match. Visual interpretation is a subjective criteria, however, conclusions were based on sound professional judgment (i.e. the judgement of experienced modelers) as to when an "optimal" fit was achieved for all conditions experienced over the calibration period.

Visual interpretation of graphic summary of data for selected time interval before and after observed data point: This procedure was an attempt to summarize the simulated 15-minute fecal coliform counts (modeled instantaneous values) for a 24- hour period before and after the observance of fecal coliform concentrations (censored). Graphics included a plot of the maximum and minimum simulated 15- minute values with associated observed point data. These graphs provided a relative comparison between simulated values and observed points for a selected window around the observed points. In general, we would expect a significant number of the observed points to fall within the upper (maximum) and lower (minimum) boundaries established from the simulated values. This, however, is only a guide as this relationship gives no insight to other spatial and temporal impacts.

Standard error: The standard error calculation was an attempt to incorporate more objectivity into the assessment. The objective with this criteria was to minimize the standard error. The calculation of the standard error (or pseudo standard error) is described in the Blackwater TMDL reports (sections 4.6.2). We considered this a pseudo standard error simply because observed data do not exist for all simulated values around the time period of the observation. From this assessment, the average standard error (across all impairments) did not exceed 318 cfu/100 ml. This was on the same order of magnitude as the lower detection limit (LDL) and the variation seen between field duplicates samples (i.e. duplicate samples taken at the same location and time).

Based on professional experience with hydrologic/water quality modeling and our careful evaluation of the calibration/validation data obtained from numerous simulations that resulted from adjustment of appropriate model parameters, we concluded that an acceptable calibration was achieved for all impaired segments. This conclusion acknowledges that some points are either over or underestimated more than we would like. However, attempts to improve the match for these points resulted in unacceptable comparisons in other areas. The difficult points are

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most likely attributed to unknown spatiotemporal variability in fecal coliform loads, possible unknown activity within the stream and/or landscape (e.g. regrowth), homogeneous assumption made for point data when an unknown heterogeneous variation most likely exists over the stream cross-section at the sampling location, and/or variations in the hydrologic response due to unknown spatial variability in precipitation.

Mr. Henry continues, ***Do the peaks in the observed data occur during low or high flow events.***

The relationship between observed fecal coliform concentration and flow at the DEQ/USGS gaging station 02056900 is shown in Figure 2.1 of the TMDL reports. As shown in Figure 2.1 and further detailed in Table 2.1, the range of concentrations observed by DEQ was from 100 cfu/100 ml to 8,000 cfu/100 ml for most stations monitored within the Blackwater River. It should be noted that the observed data provided by DEQ were censured at both ends of the range. One hundred cfu/100 ml was the lower detection limit and 8,000 cfu/100 ml was the upper detection limit. Others studies in the Blackwater River watershed, as indicated in sections 2.2.1.2-2.2.1.4, have shown concentrations as low as 5 cfu/100 ml and as high as 160,000 cfu/100 ml.

Figure 2.1 in each report presents fecal coliform concentration observed at stations specific to that report and flow measured at the DEQ/USGS gaging station 02056900. As can be seen, there is no apparent correlation between concentration of fecal coliform and flow rate at station 02056900. Values at the high detection limit of 8,000 cfu/100ml were observed throughout the flow regime. In general, the minimum concentrations were also observed throughout. The majority of the observations were made during low flow conditions. Although flow depicted in figure 2.1 is for the gaging station 02056900, analysis conducted independently by both DEQ and MapTech show a high correlation between flow at DEQ/USGS gaging station 02056900 and flow measured in upstream tributaries.

It should be noted, the conditions described above were also duplicated in the model simulations.

Please specifically discuss how high flow events affect the model (is the fecal coliform being diluted out or does wash off cause exceedances of the standard).

To illustrate the impact of high flow events, both simulated fecal coliform concentrations (cfu/100ml) and streamflow (cfs) are compared in Figure 1 for the Middle Blackwater River impairment. At the initiation of stormflow, fecal coliform concentration rapidily increases to a peak (i.e. wash off is increasing at a greater rate than flow volume) and then decreases as washoff is decreasing relative to flow volume (dilution). Simulated instantaneous peak fecal coliform concentrations for this impairment exceeded 50,000 cfu/100 ml (Note that the simulation time interval was 15 minutes). Although the instantaneous peak concentrations were high, the number of occurrances were low relative to fecal coliform concentrations from low flow receiving direct deposition. During high flows, direct deposition, which is relatively constant over selected time

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frames, is diluted. During low flows, however, the concentration increases as the flow decreases given a constant load (i.e. direct deposition). Since the state standard currently includes no provision for a minimum low flow for expected uses of the impacted stream segments, extremely low flows can dominate the analysis, particularily in stream systems that experience very low flow volumes. In the absence of minimum flow conditions, the system becomes significantly more sensitive to inputs during low volume flows than during high volume flows. This includes both initial washoff flush during lowflows and direct deposition at very low flows.

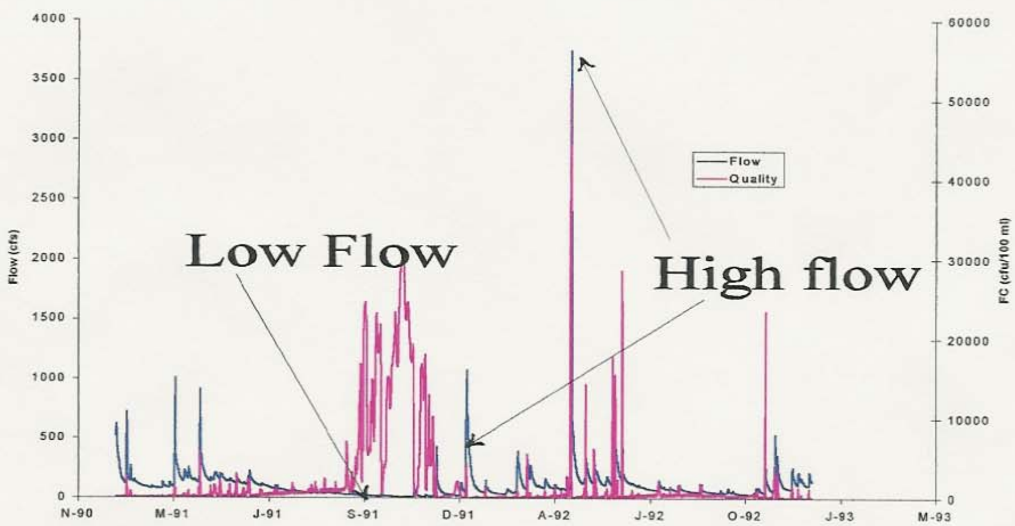

Figure 1. Modeled flow and fecal coliform concentration at the outlet of the upper four Blackwater River impairments.

To address the question as to whether or not washoff caused exceedances of the standard, the following discussion was developed and illustrates the impact of instantaneous peaks on the 30-day geometric mean.

As required by our contract, the TMDL allocations were to be developed using the State's thirty day geometric mean standard of 200 cfu/100ml) for fecal coliform. The geometric mean diminishes the effect of extreme occurrences. Because of this, it becomes important to understand the relative proportion of high events and low flow conditions occurring within a thirty day window for the our analysis period. We used the 15- minute rainfall record for the period 1994-1999 to calculate the ratio of potential storm runoff events to no storm runoff events. A potential runoff event was assumed when the rainfall intensity for a 15 minute time interval

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exceeded 0.05 in/hr. From an analysis of the rainfall record, the maximum frequency of occurrence of runoff producing events during any 30- day window were less than 7 percent (i.e. <202 instantaneous events with washoff). Conversely, approximately 93 percent of the 15- minute time intervals within a 30- day window where events with little or no storm flow (no washoff). The potential impact of these events on the geometric mean is illustrated with the following example. If we assume washoff 7% of the time (a conservative estimate) and a geometric mean for fecal coliform concentrations during non-runoff event periods as 100 cfu/100 ml, then the geometric mean of fecal coliform concentrations during runoff events could be up to four orders of magnitude higher and still meet the state's 30-day geometric mean of 200 cfu/100 ml.

Although this analysis is highly simplified, it adequately illustrates how the geometric mean diminishes the impact of extreme instantaneous fecal coliform concentrations, which was the condition in the Blackwater River TMDL analysis.

Based on a 30- day geometric mean, wash-off did not cause exceedance of the 200 cfu/100ml standard.

Mr. Henry continues with paragraph three: ***EPA has been discussing how to best justify implementation of a TMDL that includes large reductions in wildlife. Because we do not believe it can be expected to reduce wildlife by 60% or more, a phased approach to the implementation may be necessary.***

It should be pointed out that the wildlife reduction needed to meet the TMDLs are reduction in the direct deposition of fecal matter into the stream. It is debatable if these reductions are a reasonable expectation, as is the question of whether 100 percent reductions can be expected in livestock access and straight pipes. Certainly issues of a technical, practical, economic and political nature must be considered. All proposed reductions for the Blackwater River are technically feasible. Management practices for addressing pollutant sources emanating from both livestock and human sources are better defined and are generally more accepted by the public. However wildlife management is more difficult and generally less accepted by the public at large. Nonetheless, wildlife can be a significant contributor of fecal coliform. For example, as indicated in the Blackwater River by our bacteria source tracking analysis (BST) and in the Gulf Area on the eastern shore of Virginia by bacteria source tracking performed by Simmons (1997). Improvements in water quality were shown by Simmons through the management of the racoon population. Some wildlife management BMPs are available on the North Carolina State University's web site http://h2osparc.wq.ncsu.edu/descprob/wildlife.html.

Any BMP implementation strategy should include monitoring, including BST, to allow the evaluation of the effectiveness of the strategies for obtaining the TMDL goals. The inclusion of BST will allow, not only for the evaluation of the TMDL goals, but will offer insight into the need for specific strategies. For instance, if the contributions from one source become insignificant, further efforts to reduce that source would be unwarranted.

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Continuing with the final paragraph, ***Our initial thoughts are that all of the reductions which were called for in the TMDL (with the exception of wildlife) would be reduced in phase one of the implementation plan. After the completion of phase 1 of the implementation plan the State would evaluate the stream with a rigorous sampling initiative taking samples during low and high flow events. The sampling would be used to verify or improve the modeling assumptions, to determine if standards are being met, and if wildlife or any other reductions are necessary.***

We feel strongly about the importance of a phased approach coupled with continued monitoring. It goes without saying that there is a great deal of uncertainty with modeling. In an effort to reduce some of this uncertainty, we included bacteria source tracking (BST) during the TMDL development. The analysis identified livestock, wildlife and human sources of fecal coliform. In addition, the analysis indicated livestock and wildlife as the prominent sources of fecal coliform contamination. It verified our modeling design as our model results similarly indicated livestock and wildlife as significant sources of fecal coliform. Continued BST, during the implementation phase, will aid in targeting strategies to achieve desired results with minimum impact on all communities that must contribute to improve water quality.

And finally, ***The Commonwealth will review its standards to address contributions of fecal coliform from wildlife.***

Natural conditions, as well as, low flow conditions should be addressed in revising the standard. In considering revisions to the water quality standards, it is important to remember the limitations of our sampling. There are measurement uncertainties. As mentioned above, a 4,200 % difference in fecal concentrations was measured between field duplicates in the Blackwater River drainage (100 cfu/100 ml vs 4,300 cfu/100 ml). These were samples collected within five minutes of each other at the same sample location. One sample violated the State's standard and the other did not. From the literature, fecal densities within a species vary by orders of magnitude. The impacts to the TMDL allocations from these uncertainties can be significant and must be addressed in the standard.

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The Blackwater River TMDLs and the subsequent implementation plan development affords us the opportunity to evaluate the impact of various revisions to the State's water quality standards on the TMDLs. MapTech will be conducting additional BST analysis for these impairments during the course of developing the TMDL implementation plans.

Please feel free to contact me if you have any further concerns/requests.

Sincerely,

Phillip W. McClellan
President

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GLOSSARY

Note: All entries in italics are taken from USEPA (1999).

303(d). A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

Allocations. *That portion of a receiving water's loading capacity attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources. (A wasteload allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future nonpoint source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)*

Ambient water quality. *Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.*

Anthropogenic. *Pertains to the [environmental] influence of human activities.*

Antidegradation Policies. *Policies that are part of each states water quality standards. These policies are designed to protect water quality and provide a method of assessing activities that might affect the integrity of waterbodies.*

Aquatic ecosystem. *Complex of biotic and abiotic components of natural waters. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and nonliving components of the aquatic ecosystem interact and influence the properties and status of each component.*

Assimilative capacity. *The amount of contaminant load that can be discharged to a specific waterbody without exceeding water quality standards or criteria. Assimilative capacity is used to define the ability of a waterbody to naturally absorb and use a discharged substance without impairing water quality or harming aquatic life.*

Background levels. *Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.*

Bacteria. *Single-celled microorganisms. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.*

Bacterial decomposition. *Breakdown by oxidation, or decay, of organic matter by heterotrophic bacteria. Bacteria use the organic carbon in organic matter as the energy source for cell synthesis.*

Bacteria source tracking (BST). A collection of scientific methods used to track sources of fecal contamination.

Benthic. *Refers to material, especially sediment, at the bottom of an aquatic ecosystem. It can be used to describe the organisms that live on, or in, the bottom of a waterbody.*

Benthic organisms. *Organisms living in, or on, bottom substrates in aquatic ecosystems.*

Best management practices (BMPs). *Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.*

Biosolids. Biologically treated solids originating from municipal waste water treatment plants.

Box and whisker plot. A graphical representation of the mean, lower quartile, upper quartile, upper limit, lower limit, and outliers of a data set.

Calibration. *The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.*

Channel. *A natural stream that conveys water; a ditch or channel excavated for the flow of water.*

Chloride. *An atom of chlorine in solution; an ion bearing a single negative charge.*

Clean Water Act (CWA). *The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is section 303(d), which establishes the TMDL program.*

Concentration. *Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).*

Concentration-based limit. *A limit based on the relative strength of a pollutant in a waste stream, usually expressed in milligrams per liter (mg/L).*

Confluence. The point at which a river and its tributary flow together.

Contamination. *The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.*

Continuous discharge. *A discharge that occurs without interruption throughout the operating hours of a facility, except for infrequent shutdowns for maintenance, process changes, or other similar activities.*

Conventional pollutants. *As specified under the Clean Water Act, conventional contaminants include suspended solids, coliform bacteria, high biochemical oxygen demand, pH, and oil and grease.*

Conveyance. A measure of the of the water carrying capacity of a channel section. It is directly proportional to the discharge in the channel section.

Cost-share program. *A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs are paid by the producer (s).*

Cross-sectional area. *Wet area of a waterbody normal to the longitudinal component of the flow.*

Critical condition. *The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.*

Decay. *The gradual decrease in the amount of a given substance in a given system due to various sink processes including chemical and biological transformation, dissipation to other environmental media, or deposition into storage areas.*

Decomposition. *Metabolic breakdown of organic materials; the formation of by-products of decomposition releases energy and simple organic and inorganic compounds. See also* ***Respiration****.*

Designated uses. *Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.*

Deterministic model. *A model that does not include built-in variability: same input will always result in the same output.*

Dilution. *The addition of some quantity of less-concentrated liquid (water) that results in a decrease in the original concentration.*

Direct runoff. *Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.*

Discharge. *Flow of surface water in a stream or canal, or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.*

Discharge Monitoring Report (DMR). *Report of effluent characteristics submitted by a municipal or industrial facility that has been granted an NPDES discharge permit.*

Discharge permits (under NPDES). *A permit issued by the U.S. EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. The permit process was established under the National Pollutant Discharge Elimination System, under provisions of the Federal Clean Water Act.*

Dispersion. *The spreading of chemical or biological constituents, including pollutants, in various directions at varying velocities depending on the differential in-stream flow characteristics.*

Diurnal. *Actions or processes that have a period or a cycle of approximately one tidal-day or are completed within a 24-hour period and that recur every 24 hours. Also, the occurrence of an activity/process during the day rather than the night.*

DNA. Deoxyribonucleic acid. The genetic material of cells and some viruses.

Domestic wastewater. *Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.*

Drainage basin. *A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.*

Dynamic model. *A mathematical formulation describing and simulating the physical behavior of a system or a process and its temporal variability.*

Dynamic simulation. *Modeling of the behavior of physical, chemical, and/or biological phenomena and their variations over time.*

Ecosystem. *An interactive system that includes the organisms of a natural community association together with their abiotic physical, chemical, and geochemical environment.*

Effluent. *Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.*

Effluent guidelines. *The national effluent guidelines and standards specify the achievable effluent pollutant reduction that is attainable based upon the performance of treatment technologies employed within an industrial category. The National Effluent Guidelines Program was established with a phased approach whereby industry would first be required to meet interim limitations based on best practicable control technology currently available for existing sources (BPT). The second level of effluent limitations to be attained by industry was referred to as best available technology economically achievable (BAT), which was established primarily for the control of toxic pollutants.*

Effluent limitation. *Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.*

Empirical model. *Use of statistical techniques to discern patterns or relationships underlying observed or measured data for large sample sets. Does not account for physical dynamics of waterbodies.*

Endpoint. *An endpoint (or indicator/target) is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance (an indicator). A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints (targets).*

Enhancement. *In the context of restoration ecology, any improvement of a structural or functional attribute.*

Evapotranspiration. The combined effects of evaporation and transpiration on the water balance. Evaporation is water loss into the atmosphere from soil and water surfaces. Transpiration is water loss into the atmosphere as part of the life cycle of plants.

Existing use. *Use actually attained in the waterbody on or after November 28, 1975, whether or not it is included in the water quality standards (40 CFR 131.3).*

Fate of pollutants. *Physical, chemical, and biological transformation in the nature and changes of the amount of a pollutant in an environmental system. Transformation processes are pollutant-specific. Because they have comparable kinetics, different formulations for each pollutant are not required.*

Fecal Coliform. Indicator organisms (organisms indicating presence of pathogens) associated with the digestive tract.

Feedlot. *A confined area for the controlled feeding of animals. Tends to concentrate large amounts of animal waste that cannot be absorbed by the soil and, hence, may be carried to nearby streams or lakes by rainfall runoff.*

First-order kinetics. *The type of relationship describing a dynamic reaction in which the rate of transformation of a pollutant is proportional to the amount of that pollutant in the environmental system.*

Flux. *Movement and transport of mass of any water quality constituent over a given period of time. Units of mass flux are mass per unit time.*

Geometric mean. A measure of the central tendency of a data set that minimizes the effects of extreme values.

GIS. Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)

Ground water. *The supply of fresh water found beneath the earths surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.*

HSPF. Hydrological Simulation Program – Fortran. A computer simulation tool used to mathematically model nonpoint source pollution sources and movement of pollutants in a watershed.

Hydrograph. *A graph showing variation of stage (depth) or discharge in a stream over a period of time.*

Hydrologic cycle. *The circuit of water movement from the atmosphere to the earth and its return to the atmosphere through various stages or processes, such as precipitation, interception, runoff, infiltration, storage, evaporation, and transpiration.*

Hydrology. *The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.*

Hyetograph. *Graph of rainfall rate versus time during a storm event.*

IMPLND. An impervious land segment in HSPF. It is used to model land covered by impervious materials, such as pavement.

Indicator. *A measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.*

Indicator organism. *An organism used to indicate the potential presence of other (usually pathogenic) organisms. Indicator organisms are usually associated with the other organisms, but are usually more easily sampled and measured.*

Infiltration capacity. *The capacity of a soil to allow water to infiltrate into or through it during a storm.*

In situ. *In place; in situ measurements consist of measurements of components or processes in a full-scale system or a field, rather than in a laboratory.*

Interflow. Runoff which travels just below the surface of the soil.

Isolate. An inbreeding biological population that is isolated from similar populations by physical or other means.

Leachate. *Water that collects contaminants as it trickles through wastes, pesticides, or fertilizers. Leaching can occur in farming areas, feedlots, and landfills and can result in hazardous substances entering surface water, ground water, or soil.*

Limits (upper and lower). The lower limit equals the lower quartile – 1.5x(upper quartile – lower quartile), and the upper limit equals the upper quartile + 1.5x(upper quartile – lower quartile). Values outside these limits are referred to as outliers.

Loading, Load, Loading rate. *The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.*

Load allocation (LA). *The portion of a receiving waters loading capacity attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished. (40 CFR 130.2(g)).*

Loading capacity (LC). *The greatest amount of loading a water can receive without violating water quality standards.*

Margin of safety (MOS). *A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody (CWA section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).*

Mass balance. *An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving the defined area. The flux in must equal the flux out.*

Mass loading. *The quantity of a pollutant transported to a waterbody.*

Mathematical model. *A system of mathematical expressions that describe the spatial and temporal distribution of water quality constituents resulting from fluid transport and the one or more individual processes and interactions within some prototype aquatic ecosystem. A mathematical water quality model is used as the basis for waste load allocation evaluations.*

Mean. The sum of the values in a data set divided by the number of values in the data set.

MGD. Million gallons per day. A unit of water flow, whether discharge or withdraw.

Mitigation. *Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those which restore, enhance, create, or replace damaged ecosystems.*

Monitoring. *Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.*

Mood's median test. A nonparametric (distribution-free) test used to test the equality of medians from two or more populations.

Narrative criteria. *Nonquantitative guidelines that describe the desired water quality goals.*

National Pollutant Discharge Elimination System (NPDES). *The national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.*

Natural waters. *Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.*

Nonpoint source. *Pollution that originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.*

Numeric targets. *A measurable value determined for the pollutant of concern which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.*

Numerical model. *Model that approximates a solution of governing partial differential equations which describe a natural process. The approximation uses a numerical discretization of the space and time components of the system or process.*

Organic matter. *The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.*

Peak runoff. *The highest value of the stage or discharge attained by a flood or storm event; also referred to as flood peak or peak discharge.*

PERLND. A pervious land segment in HSPF. It is used to model a particular land use segment within a subwatershed (e.g. pasture, urban land, or crop land).

Permit. *An authorization, license, or equivalent control document issued by EPA or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.*

Permit Compliance System (PCS). *Computerized management information system that contains data on NPDES permit-holding facilities. PCS keeps extensive records on more than 65,000 active water-discharge permits on sites located throughout the nation. PCS tracks permit, compliance, and enforcement status of NPDES facilities.*

Phased approach. *Under the phased approach to TMDL development, load allocations and wasteload allocations are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.*

Point source. *Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.*

Pollutant. *Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).*

Pollution. *Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.*

Postaudit. *A subsequent examination and verification of a model's predictive performance following implementation of an environmental control program.*

Privately owned treatment works. *Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.*

Public comment period. *The time allowed for the public to express its views and concerns regarding action by EPA or states (e.g., a Federal Register notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).*

Publicly owned treatment works (POTW). *Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.*

Quartile. The 25^{th}, 50^{th}, and 75^{th} percentiles of a data set. A percentile (p) of a data set ordered by magnitude is the value that has at most p% of the measurements in the data set below it, and (100-p)% above it. The 50^{th} quartile is also known as the median. The 25^{th} and 75^{th} quartiles are referred to as the lower and upper quartiles, respectively.

Raw sewage. *Untreated municipal sewage.*

Receiving waters. *Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.*

Reserve capacity. *Pollutant loading rate set aside in determining stream waste load allocation, accounting for uncertainty and future growth.*

Residence time. *Length of time that a pollutant remains within a section of a stream or river. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.*

Restoration. *Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.*

Riparian areas. *Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.*

Riparian zone. *The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.*

Roughness coefficient. *A factor in velocity and discharge formulas representing the effects of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.*

Runoff. *That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.*

Seasonal Kendall test. A statistical tool used to test for trends in data, which is unaffected by seasonal cycles.

Septic system. An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.

Sewer. *A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.*

Simulation. *The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions.*

Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.

Slope. *The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).*

Spatial segmentation. *A numerical discretization of the spatial component of a system into one or more dimensions; forms the basis for application of numerical simulation models.*

Stakeholder. Any person with a vested interest in the TMDL development.

Standard. In reference to water quality (e.g. 200 cfu/100ml geometric mean limit).

Standard deviation. A measure of the variability of a data set. The positive square root of the variance of a set of measurements.

Standard error. The standard deviation of a distribution of a sample statistic, esp. when the mean is used as the statistic.

Statistical significance. An indication that the differences being observed are not due to random error. The p-value indicates the probability that the differences are due to random error (i.e. a low p-value indicates statistical significance).

Steady-state model. *Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations. Model variables are treated as not changing with respect to time.*

Storm runoff. *Storm water runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or into waterbodies or is routed into a drain or sewer system.*

Streamflow. *Discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" since streamflow may be applied to discharge whether or not it is affected by diversion or regulation.*

Stream restoration. *Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream because of urbanization, farming, or other disturbance.*

Surface area. *The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.*

Surface runoff. *Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.*

Surface water. *All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.*

Technology-based standards. *Effluent limitations applicable to direct and indirect sources that are developed on a category-by-category basis using statutory factors, not including water quality effects.*

Timestep. An increment of time in modeling terms. The smallest unit of time used in a mathematical simulation model (e.g. 15-minutes, 1-hour, 1-day).

Topography. *The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.*

Total Maximum Daily Load (TMDL). *The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.*

Transport of pollutants (in water). *Transport of pollutants in water involves two main processes: (1) advection, resulting from the flow of water, and (2) dispersion, or transport due to turbulence in the water.*

TRC. Total Residual Chlorine. A measure of the effectiveness of chlorinating treated waste water effluent.

Tributary. *A lower order-stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.*

Validation (of a model). *Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical processes under investigation. A validated model will have also been tested to ascertain whether it accurately and correctly solves the equations being used to define the system simulation.*

Variance. A measure of the variability of a data set. The sum of the squared deviations (observation – mean) divided by (number of observations) – 1.

VADACS. Virginia Department of Agriculture and Consumer Services.

VADCR. Virginia Department of Conservation and Recreation.

VADEQ. Virginia Department of Environmental Quality.

VDH. Virginia Department of Health.

Wasteload allocation (WLA). *The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).*

Wastewater. *Usually refers to effluent from a sewage treatment plant. See also* ***Domestic wastewater****.*

Wastewater treatment. *Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.*

Water quality. *The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.*

Water quality-based effluent limitations (WQBEL). *Effluent limitations applied to dischargers when technology-based limitations alone would cause violations of water quality standards. Usually WQBELs are applied to discharges into small streams.*

Water quality-based permit. *A permit with an effluent limit more stringent than one based on technology performance. Such limits might be necessary to protect the designated use of receiving waters (e.g., recreation, irrigation, industry, or water supply).*

Water quality criteria. *Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.*

Water quality standard. *Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.*

Watershed. *A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.*

WQIA. Water Quality Improvement Act.

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